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Center for Coastal Studies

3938

February 22, 2004

Karen Adams
Project Manager
Regulatory Division
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742

Re: Cape Wind Energy Project
File No. 2004-338-1

Dear Ms. Adams:

We have reviewed the draft EIS for the Cape Wind Energy Project and offer the following comments that pertain to the compatibility of the proposed project with the Horseshoe Shoal area. These comments are drawn from a report prepared by the Provincetown Center for Coastal Studies entitled, "Review of State and Federal Marine Protection of the Ecological Resources of Nantucket Sound," a copy of which is enclosed. We ask that the report be made part of the official record.

Throughout the scoping and hearing process for this project, various stakeholders and members of the general public have described Nantucket Sound variously as an area of special significance. Owing largely to its shallow waters and limited port facilities on the Cape and Islands, the public has come to know, appreciate, and use the Sound as a non-industrialized open body of water. And until recently, I think it is fair to say that the majority of people living in the region thought of the entirety of Nantucket Sound in much the same way as they think of Vineyard Sound, Cape Cod Bay, and Buzzards Bay; namely, as protected state waters.

While the public's misconception does not alter the reality of the situation, we believe that in such instances public opinion is a valid criterion for determining what is in the public interest relative to proposed alterations of the environment. In the absence of the kind of comprehensive ocean planning and management called for recently by the U.S. Commission on Ocean Policy, we believe that it is reasonable to conclude that Nantucket Sound has until now enjoyed *de facto* status as a marine sanctuary and that the scale and location of the proposed project is incompatible with this collective sense of how the Sound should be used and managed. While the DEIS provides a broad array of factual data about the proposed project, it cannot resolve the underlying public policy issues that require immediate attention.

As we reported in our 2003 study, over the course of the past thirty-two years, it has been the consistent policy of the Commonwealth of Massachusetts to maintain the Sound as an open body of water and to manage the living marine resources in a sustainable manner. Specific actions toward this end have included:

- The state legislature in 1970 included Nantucket Sound in the Cape and Islands Ocean Sanctuary, one of five sanctuaries created by the Ocean Sanctuaries Act (M.G.L. c132A, ss 12A-16F, 18 and 302 CMR 5.00). The act prohibits activities that may significantly alter the ecology or appearance of the ocean, seabed, or subsoil of a designated sanctuary. The prohibitions may be waived (except within the Cape Cod Ocean Sanctuary) upon a finding by the Department of Conservation and Recreation that the project meets a six-part test of public necessity and convenience. The principal authors of this law have said that it was the intent of the legislature to extend this degree of protection "seaward" from the mainland and islands so as to include all of Nantucket Sound.

- On December 22, 1980, the Massachusetts Attorney General and Secretary of Environmental Affairs nominated Nantucket Sound as a national marine sanctuary pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act of 1972 (16 U.S.C. 32 §§1431-1445). The 1980 nomination was designed to increase the level of integrative management, by improving federal consistency with the Massachusetts Ocean Sanctuaries Act. The nomination letter noted:

  > *The absence of marine sanctuary protection for the federal waters in the center of the Sound would negate efforts by the Commonwealth of Massachusetts to insure the environmental protection of the marine resources of this important water body through its Ocean Sanctuaries Program. Nantucket Sound must have a coordinated management regime… if the ecological, recreational, historic and aesthetic resources of the Sound are to be adequately protected.*

The National Oceanic and Atmospheric Administration (NOAA), which was charged with administering the sanctuaries program, did not have an approved program plan until 1983. As a result, the 1980 nomination by the state was neither administratively accepted nor denied. In fact, we found no record that the nomination had been formerly acknowledged by NOAA until its mention in a second nomination in 1983 (*see below*).

- On August 4, 1983, Nantucket Sound and a larger region including Nantucket Shoals and Oceanographer Canyon were nominated by an independent team of scientists and included in the original Site Evaluation List prepared for (NOAA) and published in the Federal Register (Vol. 48, No. 151). The resource evaluation team that identified Nantucket Sound as a candidate for sanctuary designation included scientists from the Virginia Institute of Marine Sciences, Woods Hole Oceanographic Institution, State University of New York at Stony Brook, Smithsonian Institution, and University of Rhode Island.

The central waters of the Sound, as you know, fall within federal jurisdiction. This was the outcome of a Supreme Court decision (*United States v. Maine et al*, 475 U.S. 89 (1986) that sought to "quiet" title to the seabed along the Atlantic coast. While the jurisdictional issue may have been laid to rest, the Supreme Court's ruling in this matter makes no ecological sense and has resulted in a highly impractical management unit. In the matter of fisheries management, for example, NOAA Fisheries subsequently concluded that it was more practical and ecologically relevant to have the Massachusetts Division of Marine Fisheries manage both the federal and state waters.

In our judgment, the Commonwealth of Massachusetts' 1980 proposal for federal/state management was visionary. Earlier this year both the Pew Oceans Commission and U.S. Commission on Ocean Policy called for a new regime of ocean management based on ecosystem, rather than political, boundaries. The Provincetown Center for Coastal Studies in January of this year, in response to the U.S. Commission's call for regional planning councils, issued a second report entitled "Toward an Ocean Vision for the Nantucket Shelf Region" that calls for the development of a regional ocean plan for all of Nantucket Sound, Nantucket Shoals, the Great South Channel, and Georges Bank. I have enclosed a copy of this report and request that it be made a part of the record as well.

Although the Provincetown Center for Coastal Studies has not taken a position for or against the Cape Wind energy project, we have concluded that the public interest would be better served if action on this permit were postponed, providing local, regional, state, and federal agencies a reasonable period of time to develop a comprehensive management plan for Nantucket Sound and adjacent waters. As we concluded in our second study, such a plan should address issues of compatible uses and incorporate some form of ocean zoning.

There are additional issues of process that require further development. The siting and permitting of offshore wind energy projects should not be conducted on an ad hoc, first-come basis. As numerous stakeholders and officials in the region have stated, projects of this should be reviewed in the context of a comprehensive ocean plan and be subject to national siting and permitting requirements.

Given the size and location of the project, issuance of a permit would arguably represent an irreversible and irretrievable allocation of public trust resources that could preempt the kind of ocean and renewable energy planning the nation requires.

Sincerely,

Peter R. Borrelli
Executive Director

Enclosures:

- "Review of State and Federal Marine Protection of the Ecological Resources of Nantucket Sound," 2003
- "Toward an Ocean Vision for the Nantucket Shelf Region," 2004

Review of State and Federal Marine Protection of the Ecological Resources of Nantucket Sound

Center for Coastal Studies
January 28, 2003

REVIEW OF STATE AND FEDERAL MARINE PROTECTION OF THE ECOLOGICAL RESOURCES OF NANTUCKET SOUND

CENTER FOR COASTAL STUDIES
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JANUARY 28, 2003

COVER: SOCIALIZING GRAY SEALS (*HALICHOERUS GRYPUS*) ON A CAPE COD BEACH
PHOTO – OWEN NICHOLS, CCS © 2002

i. Executive Summary

On October 22, 2002, the Center for Coastal Studies (CCS) was contacted by U.S. Representative William Delahunt (MA-10^{th} District) to provide a review of the existing literature pertaining to the biological resources and environmental protection of the waters of Nantucket Sound. In response to this request, CCS has prepared the following document, detailing the biological significance of the species contained therein, as well as a review of pertinent existing and proposed state and federal protection of these waters. The purpose of this review is to gather existing facts regarding the biodiversity and ecological significance of the region and to highlight areas where additional study may be necessary.

Nantucket Sound contains significant ecological, commercial and recreational resources that have been at the heart of several past nominations for enhanced environmental protection and conservation policies within the region. The biological diversity and unique habitat areas of Nantucket Sound led the Commonwealth of Massachusetts to nominate the area for National Marine Sanctuary status in a 1980. The resources of Nantucket Sound were again deemed worthy of consideration for National Marine Sanctuary status by the resource evaluation committee appointed by the National Marine Sanctuary Program in 1983. These resources are equally significant today. Nantucket Sound is a recognized habitat for many state and federally protected species, including roseate terns, piping plovers, leatherback sea turtles, loggerhead sea turtles, Kemp's Ridley sea turtles, and grey seals.

Our review uncovered several localized studies and species-specific biological surveys throughout published literature, unpublished reports and on-going data collection. While of intrinsic value, these studies have not addressed management mechanisms for integrating and coordinating environmental management for resident or migratory species that rely on the Sound. As a result, much of the available information considers only pieces of an ecological whole, resulting in fragmented understanding of dynamic ecosystem processes and species interactions.

Current management focuses upon ecologically arbitrary divisions of a contiguous coastal resource resulting from overlapping state and federal jurisdiction of these waters. Past state and federal nominations to protect these waters as a national marine sanctuary suggest the inherent ecological, commercial, and recreational values of Nantucket Sound. CCS recommends a multi-disciplinary taskforce study of the Nantucket Sound biogeographical region to assess the existing habitat, species utilizations, and commercial and recreational values of the area in order to facilitate consistent environmental management and conservation of protected marine resources. The existing data collected by state, federal, and private agencies will greatly facilitate such a study by providing a base for designing a broad study of the entire system. Development of comprehensive ecosystem management begins with thorough, scientific evaluation of the resources and processes of the entire system designed to support a unified environmental policy for the continued use, study and protection of this valuable coastal resource.

Funding for this report was made possible in part by a grant from
The Sudbury Foundation in collaboration with the Association to Preserve
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of the Center for Coastal Studies

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1.0 Introduction

The Center for Coastal Studies (CCS) is a non-profit research, education and conservation organization with over 25 years of service on a variety of coastal and marine issues. On October 22, 2002, CCS received a written request from U.S. Representative William Delahunt to provide a review of the existing literature pertaining to the biological resources and environmental protection of the waters of Nantucket Sound. Of particular interest in this regard were past attempts to gain marine sanctuary status for the waters of Nantucket Sound, as well as an overview of present ecological significance of the region.

The initial efforts to classify the waters of Nantucket Sound as a marine sanctuary were undertaken by the state Legislature with the passage in 1970 of the Massachusetts Ocean Sanctuaries Act. This legislative action authorized the creation of five ocean sanctuaries, with Nantucket Sound explicitly included within the Cape and Islands Ocean Sanctuary. Subsequent jurisdictional disputes culminated with federal jurisdiction over the central waters of Nantucket Sound, and a "hole-in-the-doughnut" scenario of unprotected federal waters nearly completely surrounded by protected state waters. To resolve the dilemma of dual management, the Commonwealth in 1980 advanced a proposal to designate Nantucket Sound as a National Marine Sanctuary. In 1983, Nantucket Sound was placed on the Site Evaluation List for National Marine Sanctuary status by a resource evaluation committee appointed by the National Marine Sanctuary Program. To date, however, Nantucket Sound remains a multi-jurisdictional region, with state jurisdiction over the state ocean sanctuary waters and federal jurisdiction over the central, "hole-in-the-doughnut" portion of the Sound.

CCS has completed a preliminary review of available literature pertaining to the marine resources of Nantucket Sound. This review serves to document published and unpublished data regarding marine and coastal resources of the area, and to highlight areas where further and/or more intensive studies may be needed to fully evaluate the current status of this system. In preparing this review, it has become apparent that the jurisdictional boundaries that regulate management and research activities are incompatible with a holistic, ecosystem-based approach to managing the resources within and relying upon the dynamic and non-fragmented ecosystem of the Nantucket Sound region.

The Commonwealth has demonstrated a will to protect and conserve the resources of Nantucket Sound since its initial attempt to classify those waters as an ocean sanctuary. In 1980, the Commonwealth presented a compelling argument for federal recognition of those resources by nominating Nantucket Sound for National Marine Sanctuary status. The National Marine Sanctuary Program's site selection committee acknowledged and confirmed the Commonwealth's interest in protecting Nantucket Sound in its 1983 Final Report.

The Nantucket Sound region is unquestionably a healthy and productive ecosystem. However, the complexities of the jurisdictional arrangement have needlessly complicated scientists' and managers' ability to fully assess the ecological significance of the region and many of its marine species. Therefore, CCS concurs with the Commonwealth's 1980 recommendation that Nantucket Sound be managed as a single ecological unit so as to ensure that the entire region receive the level of environmental protection afforded to those portions of the Sound within the Cape and Islands Ocean Sanctuary.

2.0 Geography of Nantucket Sound

Nantucket Sound includes 163 square nautical miles of water and seabed between Cape Cod, Vineyard Sound, the islands of Martha's Vineyard and Nantucket extending seaward beyond Monomoy and Nantucket Islands. An approximate latitudinal boundary spans from 41° 12' N to 41° 40' N, while the longitudinal boundary spans approximately from 69° 55' W to 70° 36' W.

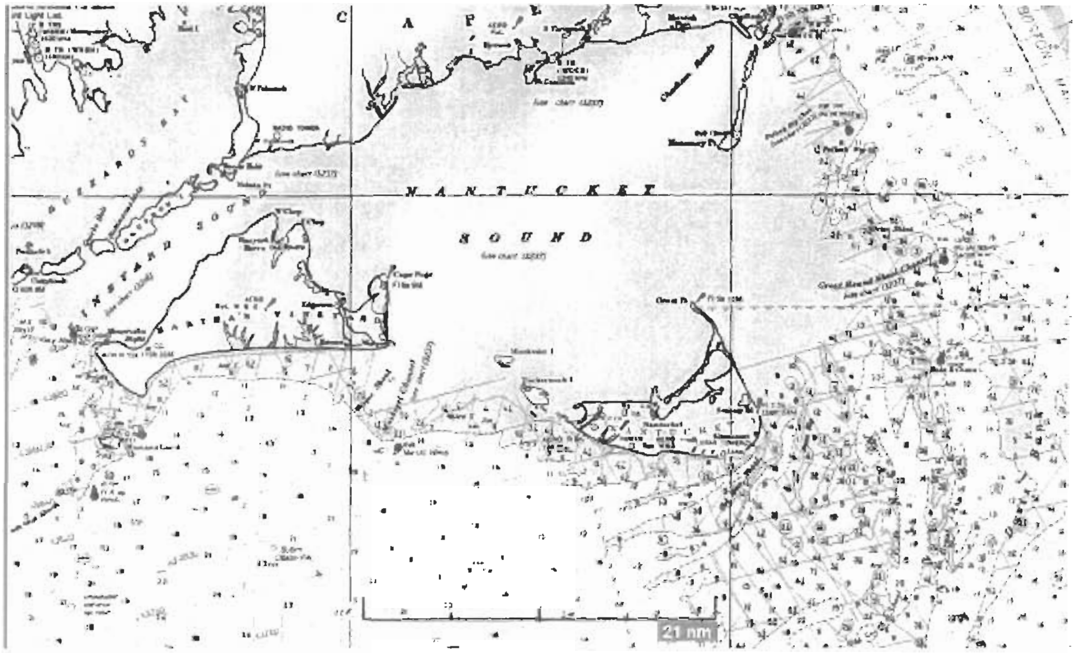

Figure 1 -- Nantucket Sound (from NOAA Chart 13200)

Nantucket Sound borders shallow shoal waters of the Atlantic Shelf to the east, deeper Atlantic Shelf waters to the south, Vineyard Sound to the west and Cape Cod to the North. The submerged land within 3 miles from mean low water is within the boundaries of the Cape and Islands Ocean Sanctuary. Waquoit Bay National Estuarine Research Reserve (NERR) borders Nantucket Sound on the northern shore. Monomoy National Wildlife Refuge comprises the northeastern terrestrial boundary of the Sound.

Nantucket Sound is situated at a confluence of the cold Labrador currents and the warm Gulf Stream. This creates a unique coastal habitat representing the southern range for Northern Atlantic species and the northern range for Mid-Atlantic species. The transitional ecology of the region is consistent with both the biogeographic location and the transitional geology of the glacially deposited sediments that form Nantucket Sound. Nantucket Sound is characterized by an extreme richness of biological diversity, containing habitats that range from open sea to salt marshes. The complex networks of habitat utilization and species competition within the Sound remains an area for significant scientific research.

The largest of the many shoals within Nantucket Sound is Horseshoe Shoal. Horseshoe Shoal covers approximately 35 square miles with depths averaging between 13 and 40 feet. The major navigational channel in Nantucket Sound is Main Channel, adjacent to the southern edge of Horseshoe Shoal. Nantucket Sound is subject to changes in the physical dynamics of its many shoals, with fluctuations caused by regional climatological and oceanographic phenomena.

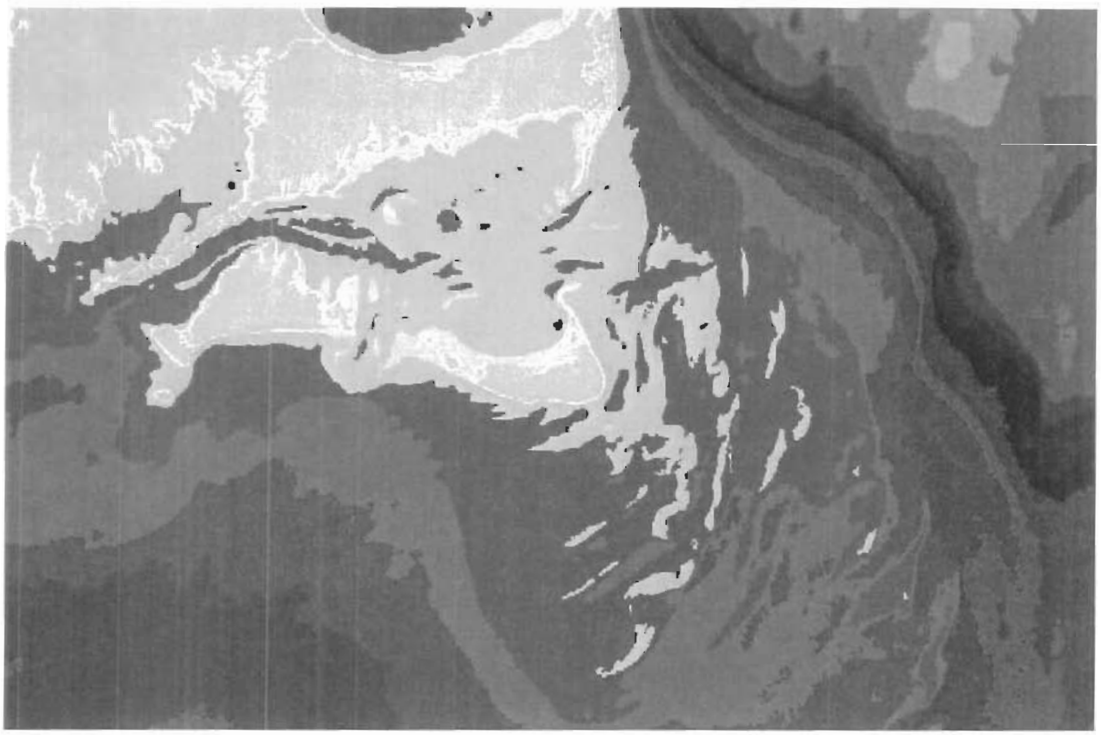

Figure 2 -- Bathymetry of Nantucket Sound and Nantucket Shoals

3.0 Overview of State and Federal Marine Protected Areas

3.1 Massachusetts Oceans Sanctuaries

The Massachusetts Oceans Sanctuary Act (M.G.L. c. 132A, §§ 13-16, 18) attempts to *protect the ecology or the appearance of the ocean, the seabed and subsoil from any exploitation, development or activity that would seriously alter or endanger those resources* (M.G.L. c. 132A, §§ 12A, 321 CMR Section 5.00). This statute does not regulate fisheries or living resource extraction, but does regulate non-renewable resource development, discharging, marine construction, and shoreline alteration. Proposal for construction, development, or alteration of these waters are regulated through the Massachusetts Department of Environmental Management and Massachusetts Office of Coastal Zone Management. These sanctuaries extend three (3) miles from the state's coast. However, in the case of the Cape Cod Bay Ocean Sanctuary this limit was extended to envelop the entirety of the Bay.

3.2 National Marine Sanctuary System

The National Marine Sanctuary system was established to *identify, manage, and conserve areas of the marine environment that are nationally significant due to conservation, recreational, ecological, historical, scientific, educational, cultural, archaeological or aesthetic qualities* (National Marine Sanctuaries Act, 16 USC Section 1431). The regulations for National Marine Sanctuaries are sanctuary-specific and intended to provide selected areas comprehensive protection of the marine resources contained therein. The National Marine Sanctuary Program is administered by the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA).

3.2.1 Nomination Criteria and History

National Marine Sanctuaries can be designated in two ways: administratively, through the actions of the Secretary of Commerce; and legislatively, through an act of Congress. Prior to September 7, 1982 any person could recommend a site for consideration. Subsequent to 1982, NOAA's National Marine Sanctuaries Program contracted with Chelsea International Corporation of Washington D.C. to prepare a Site Evaluation List from which future marine sanctuaries might be chosen. From the Site Evaluation List, active candidates for sanctuary designation are chosen for their conservation, ecological, recreational or aesthetic values. Sanctuary designation requires the Secretary of Commerce to publish a notice of intent in the *Federal Register* informing the public of NOAA's intention to consider an area for sanctuary designation. A draft environmental impact statement on the proposed designation, the draft management plan, and draft regulations are prepared. This draft environmental impact statement (DEIS) must include a resource assessment report and maps which depict the boundaries of the area.

During the review period the proposal goes before the House Committee on Resources and the Senate Committee on Commerce, Science and Transportation. Finally, the Secretary must publish a notice to designate a national marine sanctuary in the *Federal Register* and include final regulations. Another 45-days of Congressional review must elapse before a sanctuary is designated.

Sanctuaries are managed according to site-specific management plans prepared by the National Oceanic and Atmospheric Administration's (NOAA), with multiple opportunities for public comments. The philosophy behind National Marine Sanctuary management is what NOAA calls an "*ecosystem approach to marine environmental protection.*" While sanctuary management plans are site-specific, sanctuary regulations generally prohibit discharging materials into the protected area, alteration of the seabed, disturbance of cultural resources, and oil, gas and mineral production (with a grandfather clause for preexisting operations).

4.0 Marine Protection in Nantucket Sound

Nantucket Sound is a multi-jurisdictional biogeographical region. The Commonwealth of Massachusetts is responsible for management of the waters and sea floor of the Cape and Islands Ocean Sanctuary, including all submerged lands within 3 miles of the low water line (Appendix A, Table 1). Meanwhile, the federal government has jurisdiction over all waters and sea floor more than 3 miles from the Massachusetts coastline (Appendix A, Table 2). Because the portions of the Cape and Islands surrounding the Sound are some 25-30 nautical miles apart in some areas, the 3-mile envelope of the state-protected sanctuary excludes a significant portion of the interior of the Sound. The result is that this one, contiguous ecosystem is owned and managed by two distinct entities without a formal, unified management strategy.

There have been both state and federal efforts to integrate management of Nantucket Sound under various marine protected area designations. While the issue of jurisdictional boundaries in Nantucket Sound is essentially a political issue, management of the marine resources of the Sound is best achieved through an ecosystem-based approach to managing the biogeographical region. The fact that both the Commonwealth of Massachusetts and the U.S. government have proposed Nantucket Sound for National Marine Sanctuary status (described in Section 4.2, below) suggests that there is a general consensus regarding the level of ecological richness and environmental integrity of the Nantucket Sound region.

4.1 Cape and Islands Ocean Sanctuary

When Massachusetts passed the Ocean Sanctuaries Act (M.G.L. c. 132A, §§ 13-16, 18), in 1970, this action authorized the creation and maintenance of five (5) Ocean Sanctuaries. The Ocean Sanctuaries are managed by the Massachusetts Executive Office of Environmental Affairs (EOEA), with management activities carried out by several other state agencies, including 1) the Department of Environmental Management, 2) the Division of Marine Fisheries, 3) the Department of Environmental Protection, 4) the Office of Coastal Zone Management.

The Massachusetts Ocean Sanctuaries Act obliges the Department of Environmental Management (DEM) to protect the sanctuaries from any development or activity that would damage the ecology or aesthetics of the area. Specifically prohibited within Massachusetts Ocean Sanctuaries are the construction of physical structures on the seabed, the building of offshore or floating power plants, the drilling through or removal of mineral resources, gases or oils. Also banned are dumping of wastes and incineration of private or commercial wastes by any ship moored or floating within a sanctuary.

The Cape and Islands Ocean Sanctuary is defined in M.G.L c. 132A §§ 13:

> The Cape and Islands Ocean Sanctuary is bounded and described as follows: Beginning at a point on the mean low-water line at the southernmost point of Monomoy Point; thence due south to a point in the Atlantic Ocean three miles due south (180 Degrees True) of the mean low-water line at the southernmost point of Monomoy Point; thence due east (90 Degrees True) to the Exterior Line

of the Boundary of the Commonwealth as established on the aforementioned Marine Boundary Map; thence in a generally southerly and then westerly direction along said Exterior Line to the point of intersection with the extension of the lateral boundary of Rhode Island and Massachusetts; thence northerly along said lateral boundary to the mean low-water line near Quicksand Point; thence following the mean low-water line around Buzzards Bay, the Cape Cod Canal to the Bourne-Sandwich town boundary, and the southern portion of Cape Cod to the point of intersection in Pleasant Bay with the western boundary of the Cape Cod National Seashore; thence southerly along said boundary; thence by the shortest distance to the mean low-water line of Monomoy Island; thence to the point beginning by following the mean low-water line of the western side of Monomoy Island; and meaning and intending to include the area seaward of the mean low-water lines of Nantucket, Martha's Vineyard, Elizabeth and other islands; and *meaning and intending to include the following bodies of water:* ***Nantucket Sound***, Vineyard Sound, Buzzards Bay, the Cape Cod Canal, Pleasant Bay, and portions of the Atlantic Ocean. [emphasis added]

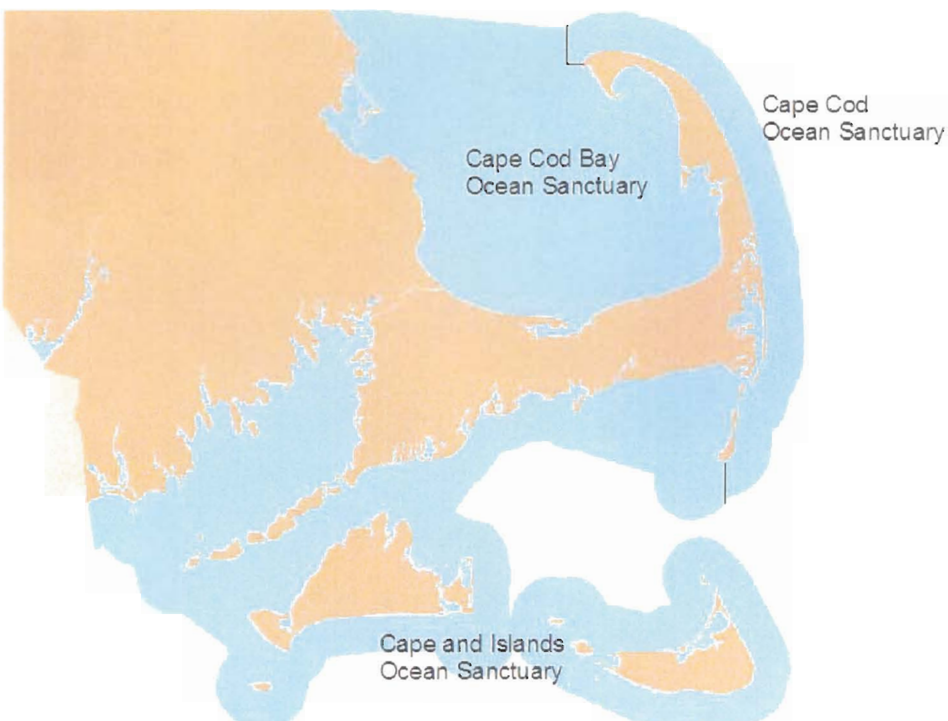

Figure 3 -- Massachusetts Ocean Sanctuaries

The Massachusetts Legislature made clear its intention to include the entirety of Nantucket Sound in the Cape and Islands Ocean Sanctuary. Later nominations for

National Marine Sanctuary status for Nantucket Sound (see Section 4.2), demonstrate that the Commonwealth has had a long-standing interest in promoting an integrated system for managing the Sounds resources. In fact, a major rationale for the Commonwealth's 1980 nomination was to gain equal protection for the both state and federal waters, as well as to combine management authority in a unique and relatively holistic way.

4.2.1 National Marine Sanctuary Nominations for Nantucket Sound

4.2.2 1980 Nomination

In 1980, the Massachusetts Secretary of Environmental Affairs and the Attorney General nominated Nantucket Sound for National Marine Sanctuary status pursuant to Title III of the Marine Protection, Research and Sanctuaries Act of 1972 (16 U.S.C. 32 §§1431-1445, also known as the National Marine Sanctuaries Act). The National Marine Sanctuaries Act authorizes the Secretary of Commerce to designate and manage areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or aesthetic qualities. The primary objective of this law is to protect marine resources, such as unique habitats. The Act also directs the Secretary to facilitate all public and private uses of Sanctuary resources that are compatible with the primary objective of resource protection.

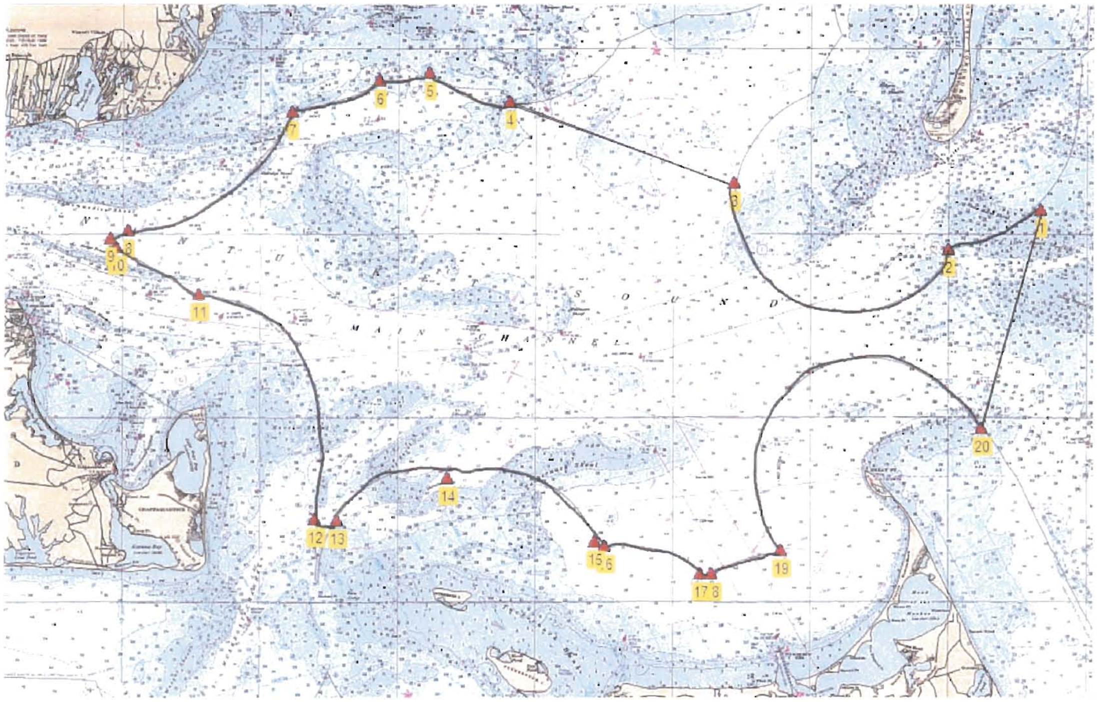

Figure 4 -- Proposed Boundary for Nantucket Sound National Marine Sanctuary in 1980 Nomination

The 1980 Nantucket Sound nomination was an attempt by the Commonwealth to secure protection for the portion of the Sound not within the Cape and Islands Ocean Sanctuary. This comprehensive nomination compiled available documentation demonstrating a host of ecologically and economically significant marine resources within this area, including finfish, shellfish, marine mammals, reptiles, birds, and rare and endangered marine plants. The 1980 nomination pointed to the need for additional research into the presence of cultural resources, fisheries, sea birds and marine mammals within Nantucket Sound. The central waters of Nantucket Sound were nominated "for their value as a habitat area, species area, unique area and a recreational and aesthetic area." (EOEA 1980 Nomination p. 5)

The Commonwealth's 1980 nomination pointed to the significant amount of conservation and recreation areas in the region of Nantucket Sound. The large extent of protected land and wetlands surrounding Nantucket Sound likely serves as habitat for the rich variety of species using the Sound. The Commonwealth's nomination also advocated protection of the important educational, historic and cultural values of the numerous shipwrecks scattered throughout the Sound.

Under the 1980 nomination, NOAA would have ultimate responsibility for the overall management of the proposed Sanctuary, while EOEA would be responsible for daily on-site management operations. The 1980 nomination was designed at increasing the level of integrative management, by improving the federal consistency with the Massachusetts Ocean Sanctuaries Act. According to the Commonwealth's nomination:

> *The absence of marine sanctuary protection for the federal waters in the center of the Sound would negate efforts by the Commonwealth of Massachusetts to insure the environmental protection of the marine resources of this important water body through its Ocean Sanctuaries Program. Nantucket Sound must have a coordinated management regime... if the ecological, recreational, historic and aesthetic resources of the Sound are to be adequately protected.*

This nomination specified a holistic approach for management of the Sound, but implementation may have been complex due to the overlapping responsibilities under the proposed management arrangement. It is not clear whether this complexity affected its consideration by NOAA. No action was taken with respect to this nomination because NOAA did not have a program plan for the sanctuary system in place until 1983. As a result, the nomination was neither administratively accepted nor declined – in fact we found no record that the nomination had been formally acknowledged by the program until its mention in the later 1983 nomination, described below.

4.2.3 1983 Nomination

On August 4, 1983, Nantucket Sound, and a larger region including Nantucket Shoals and Oceanographer Canyon, were selected for the Site Evaluation List published in the *Federal Register* (Vol. 48, No. 151). Three other sites from the North Atlantic region were placed on the Site Evaluation list along with the proposed Nantucket Sound site. Of these sites, Stellwagen Bank was selected for sanctuary designation.

According to the National Marine Sanctuary Site Evaluations Recommendation and Final Reports (Chelsea International Corporation 1983):

> *The North Atlantic region contains two distinct biogeographic regimes... These two regimes meet in the area south of Cape Cod, and the transition area itself is as important as the two major regimes.*

Nantucket Sound is clearly a unique transitional area supporting significant biological productivity and diversity. In reviewing the Nantucket Sound proposal, the resource evaluation committee recognized the obstacles inherent in managing multi-jurisdictional areas and the need to incorporate ecosystem boundaries into less pliable management boundaries. The large "swath" included in the several Nantucket Sound proposals was considered a general "study area boundary" owing to the lack of ecosystem-focused research in the region.

Despite a clear representation of the ecological, economic, and aesthetic values contained in Nantucket Sound, the area was not selected for inclusion in the marine sanctuary program. Several governmental and private agencies commented on behalf of Nantucket Sound, citing the ecological significance of the area. Such agencies include the Massachusetts Marine Fisheries Commission, the Cape Cod Museum of Natural History, the Massachusetts Division of Fisheries and Wildlife, and the Humane Society of the United States, among others.

5.0 Review of Jurisdictional History of Nantucket Sound

As a component of the 1980 nomination, the Commonwealth of Massachusetts referenced case law that might aid in the conclusion that the Sound was of particular ecological significance, linked to the ecological continuity between state and federally owned portions of these waters. Under statute (43 U.S.C. 29 §§1301, 1311) and case law (*United States v. Maine*, 423 U.S. 1 (1975)), states have jurisdiction over all submerged lands within the 3-geographical mile zone, and the U.S. has title to the seabed more than 3-miles from shore. This is the jurisdictional delineation that is currently recognized in Nantucket Sound. This jurisdiction is in no way reflective of larger ecosystem boundaries, which are the increasing focus of integrated coastal zone management regimes.

The present multi-jurisdictional status of Nantucket Sound is a result of the federal effort to quiet title to the seabed along the Atlantic coast (*United States v. Maine et al.*, 475 U.S. 89 (1986)). Several states took exception to sections of the 1986 Special Master's Report on delimitation of the jurisdictional boundaries. One such exception was made by Massachusetts regarding the status of Nantucket Sound (*Massachusetts Boundary Case*, 475 U.S. 89, 94 n.9). The Commonwealth's argument has its roots in the American interpretation of English common law. Under common law, "county waters" were defined by an ambiguous line-of-sight test, which was presumed to have been met for purposes of the proceeding. The Commonwealth's case rested on the position that "ancient title" was conferred to the succeeding local jurisdiction by the English Crown in the Treaty of Paris, which ended the Revolutionary War. Furthermore, the Commonwealth argued that the United Nations' Convention of the Territorial Seas and Contiguous Zone ("Convention" 15 U.S.T. 1607, T.I.A.S. No. 5639 (1958)), provides for "historic bays." The U.S. argued that the United Nations report entitled "Juridicial Regime of Historic Waters, Including Historic Bays (U.N. Doc. A/CN.4/143 (1962)) presented a 3-part definition of a historic bay including: 1) exercise of authority over the area, 2) with continuity of authority, and 3) acquiescence of foreign nations - the maritime equivalent of title acquired by adverse possession - which was not met by the Commonwealth with respect to Nantucket Sound. The term "ancient title" is not defined in the Convention, but according the U.N. report "to base the title on occupation is to base it on a clear and original title which is fortified by long usage."

The Report of the Special Master in the *Massachusetts Boundary Case* concluded that Nantucket Sound had an historic role in the development the colonial economy of Nantucket and Martha's Vineyard. However, the United States Supreme Court ruled that "the Commonwealth did not effectively "occupy" Nantucket Sound so as to obtain "clear original title" and fortify that title "by long usage" before the seas were recognized to be free. The Supreme Court wrote that "Unless we are to believe that the self-interested endeavors of every seafaring community suffice to establish 'ancient title' to the waters containing the fisheries and resources it exploits, without regard to the continuity of usage or international acquiescence necessary to establish 'historic title', solely because exploitation pre-dated the freedom of the seas, then the Commonwealth's claim cannot be recognized."

The Nantucket Sound jurisdictional boundaries delineated by the U.S. Supreme Court (475 U.S. 89, 94) have produced an "enclave" of federally owned waters partially surrounded by state waters. No distance between mainland and/or the fringe islands exceeds 10 geographical miles. At the widest reach, between Monomoy and Great Point, the eastern entrance to Nantucket sound is 9.2 miles. Given the 3-mile state boundary, enclosing the embayment would require a straight line only 3.2 miles long. The western entrance to Nantucket Sound leads directly from Vineyard Sound, which, as mentioned, is within state jurisdiction. Beyond Vineyard Sound are either state waters (Buzzards Bay) or high seas, such that Nantucket Sound communicates vessels from high seas through state waters to high seas. Nantucket Sound meets the definition of inland waters as set forth by the U.S. in 1930.

6.0 Marine Resources of Nantucket Sound

Nantucket Sound possesses significant marine habitat for a diversity of ecologically and economically important species. Directly adjacent to the deeper waters of the Great South Channel, the Sound has particular significance for several federally-protected species including the gray seal (*Halichoerus grypus*), roseate tern (*Sterna dougallii*), piping plovers (*Charadrius melodus*), leatherback sea turtle (*Dermochelys coricea*), Atlantic Ridley sea turtle (*Lepidochelys kempi*) and a variety of commercially and recreationally valuable fisheries. Despite this, there has been insufficient scientific study of the area to assess the status of these habitats or the living marine resources of the Sound. The following sections highlight the dominant, economically significant, or conspicuous species presently inhabiting the region.

6.1.1 Marine Mammals

The waters of Nantucket Sound provide habitat potential for several species of seals and porpoises, including the gray seal, harbor seal, and harbor porpoise. Once hunted to the edge of extinction within the Gulf of Maine, harbor and gray seal populations are once again on the rise within this region. These waters are of particularly significant to gray seals which have a well-documented and growing breeding colony in Nantucket Sound, representing the southern-most breeding colony in the world, and the only known breeding colony in the United States. The breeding population at Muskeget Island rose from a maximum of 13 in the 1970's to over 1,500 in the 1990's. This rise can be attributed to increasing environmental awareness and their protection under the Marine Mammal Protection Act.

The gray seal is listed as "special concern" species on the Massachusetts List of Endangered, Threatened and Special Concern Species (321 CMR 10.60). While the species is not endangered globally, other North Atlantic grey seal populations are listed under the World Conservation Union (IUCN) Red List. The status of the gray seal population and the level of human-caused mortality and serious injury in U.S. waters is unknown, but populations are believed to be increasing.

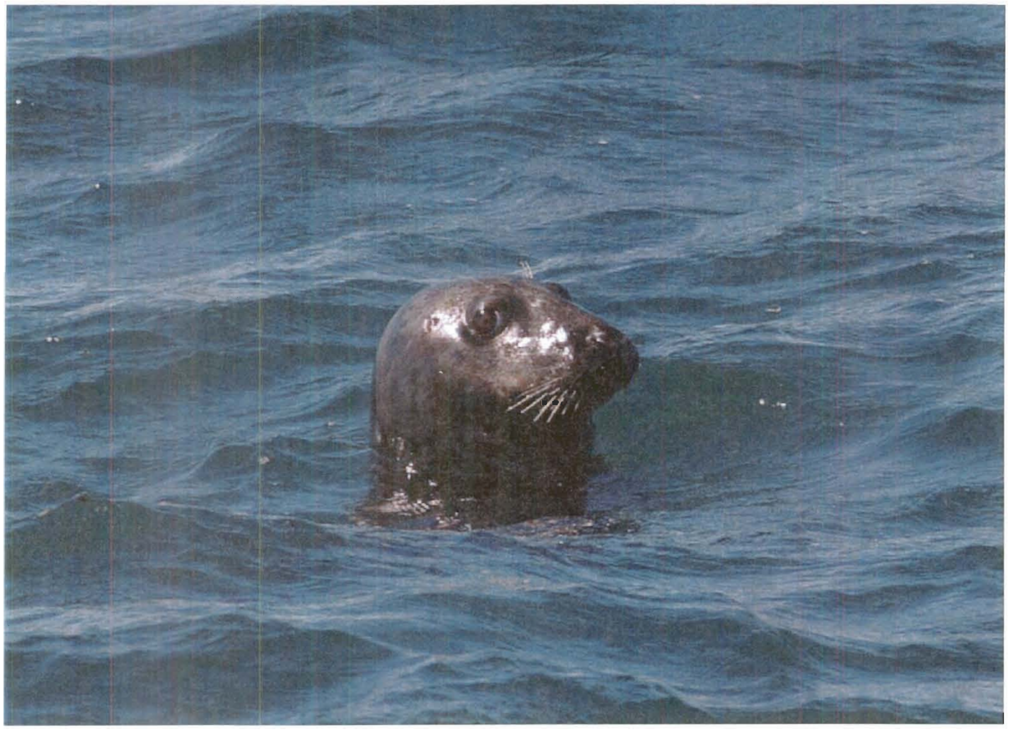

Figure 6 -- Gray seal (*Halichoerus grypus*) spotted in the Sound. (CCS © 2002)

The Western North Atlantic gray seal population is divided into two non-interbreeding communities, with 93% of the southern community located within Nantucket Sound. This division of breeding communities renders the Nantucket Sound habitat essential to the sustenance of this population. Additionally, this dichotomy provides a fertile area of study into intra-species genetics and population studies significant to this and other marine and terrestrial mammal species. With respect to the genetic uniqueness of this population, the gray seals' dependence on the waters of Nantucket Sound strongly support protection of these and adjacent waters employing an ecosystem approach to management.

In contrast to the literature pertaining to gray seals, our review of the limited number of scientific surveys of the Sound has revealed a scarcity of cetacean sightings within this specific body of water. These limited findings may be explained in part by the shallow depth of the region, but may also be linked to the minimal, if any, systemic observation of the area. As an example, CCS has frequently observed cetaceans within equally shallow water in and around

Provincetown, Massachusetts, as species may follow food sources migrating from more suitable deepwater habitats. Similarly, waters directly adjacent to Nantucket Sound have been shown to be of particular significance to a host of marine mammals, linked to major migratory routes for several species. While the predominantly shallow waters of the Sound may limit the direct habitat potential for charismatic marine mammal species, the shoal waters are of keystone significance to essential food species that drive the larger marine ecosystem.

To better assess the significance of the region, CCS is coordinating efforts to perform an aerial survey of Nantucket Sound and adjacent waters to specifically address the lack of quantitative study. Specifically, Endangered North Atlantic right whales (*Eubalaena glacialis*) are known to congregate seasonally in the Great South Channel and Cape Cod Bay, and have been reported in Vineyard Sound, Buzzards Bay and Cape Cod Canal. In fact, there have been three (3) sightings of right whales in Nantucket Sound since 1959. Adjacent to a significant migratory passage for a diversity of whale species, sightings of humpbacks, pilot whales, and finback whales have also been reported within the Sound. Had regular surveys been conducted historically in the Sound, the potential exists for more definitive evidence of cetacean utilization of this habitat.

6.2 Avian Species

The Nantucket Sound eco-region contains pristine estuaries, extensive shoals and long stretches of undeveloped coastline. Vast numbers of seabirds and waterfowl congregate to utilize near-shore shoals to feed and rest, especially during the winter season. The region includes parts of the largest winter habitat for waterfowl on the east coast of the United States. The Monomoy National Wildlife Refuge exemplifies the diversity and productivity of the Nantucket Sound region's avian habitat. Protected waters, shoals, tidal flats, salt marshes, dunes and beaches combine to create one of the most significant bird habitats in New England. The extensive conservation acreage adjacent to Nantucket Sound allows many terrestrial species to utilize distinct habitat niches in the region. The abundance and diversity of avian species within the Nantucket Sound eco-region warrant considerable future research before spatial and temporal scales of utilization are comprehensively understood.

Located within the Atlantic Flyway, Nantucket Sound possesses great habitat significance for a host of avian species, providing breeding, nesting resting and foraging habitat. As detailed in available documentation on Nantucket Sound, common eiders (*Somateria mollissima*), black scoters (*Melavitta nigra*) and surf scoters (*M. perspicillata*) congregate in the fall and winter within the shoal waters in the hundreds of thousands, while various species of terns are abundant in the coastal zone including the common tern (*Sterna hirundo*), least tern, (*S. albifrons*), roseate tern (*S. dougallii*) and arctic tern (*S. paradisaea*). The roseate tern is classified as an endangered species. The coast of Nantucket Sound is breeding habitat for the piping plover (*Charadrius melodus*), a threatened species.

Figure 6 – Common Eiders (*Somateria mollissima*) socializing. (CCS © 2002)

While a variety of public and private organizations frequently observe avian species within this region, no formal survey of species diversity, habitat utilization, or breeding success has been reported for Nantucket Sound.

From the literature reviewed, it is clear to CCS that Nantucket Sound possesses significant habitat for a diversity of commercially and recreationally important fish, marine mammal and avian species. As compelling as these data are, it is equally clear that further study should be completed to provide a timely and accurate representation of the present coastal and marine resources of the Sound. Furthermore, future study should consider individual species counts within a larger, ecosystem concept. The purely descriptive reports of the past should be replaced by estimates of diversity, species interactions, sustainability, and ecosystem health or stability to more accurately portray the present and future of this ecosystem – towards developing suitable management strategies.

7.0 Summary

Presently, Nantucket Sound is managed by several different state and federal agencies, as described above. The result of these ecologically arbitrary divisions of a contiguous marine ecosystem is that managers are unable to gain a comprehensive understanding of the spatial and temporal ecosystem dynamics and marine resources. Individual private and governmental agencies focus upon isolated components of a complex and diverse ecosystem. Increasingly, ecologists, environmental managers, and regulatory agencies have recognized the value of ecosystem-scale strategies for the protection of natural resources. Fragmented management polygons have been shown to lead to increased edge effects, compartmentalization of species and/or habitats, and discrepancies in policies and management arrangements. Within a marine environment, fragmentation can hinder comprehensive assessment of marine resources and evaluation of recreational uses or anthropogenic impacts on the biogeographical region.

7.1 Future Scientific Assessment

Our review of existing literature demonstrates that ecosystem-scale studies with directed management strategies are limited to date. Finite studies of portions of the resource or studies directed at one species or group of species results in a fragmented understanding of the system as a whole and only speculative estimates of ecosystem processes. While all reports suggest the region is relatively healthy, ecologically rich, and economically valuable, CCS concludes that a comprehensive study of the system as an ecological unit is required to confirm and understand these findings on an ecosystem-scale before broad management decisions can be made. Given this approach, subsequent management strategies should be designed for one contiguous ecological unit, rather than for finite management polygons. This peer-reviewed assessment protocol must be developed both to establish a baseline and to serve as a template for future, ongoing study of these waters. Establishing these protocols would insure that informed management strategies be developed, and their efficacy fully evaluated, to promote continued sustainable use of this important ecosystem.

A comprehensive ecological assessment of the Nantucket Sound biogeographical area would require a multi-disciplinary research team to develop a system-wide understanding of 1) physical oceanographic and geological processes 2) marine and benthic community structure and ecology 3) fisheries 4) marine mammal and reptile habitat and 5) avian habitat. Each of these broad research areas contains crucial skill sets from which to use the existing literature, rapid assessment surveys and other research tools to develop an understanding of the marine environment. A reasonably comprehensive ecological assessment of Nantucket Sound, as discussed above, could be achieved within roughly one year. Such an assessment would naturally include an ecosystem mapping component.

While existing literature addresses many of the physical and geologic processes in Nantucket Sound, a comprehensive review of the region should focus on patterns of marine habitat available within the dynamic shoal environments. Submerged aquatic vegetation, including eel grass (*Vallisneria spiralis*), provides essential habitat for juvenile fish and shellfish, and a benthic survey of Nantucket Sound should be part of a comprehensive ecosystem study. Fisheries have been regularly surveyed in Nantucket Sound such that this area of research should be relatively rich in data. Analysis in this area should specifically address ecological implications of shellfish and finfish dynamics. There is significant on-going marine mammal research in the Nantucket Sound region, and this information should clearly be included in a comprehensive study. As noted, the Nantucket Sound region has exceptional habitat for an abundant mix of avian species, however, there is insufficient data on community patterns, habitat pressures, and population dynamics affecting this region.

7.2 Recommendations and Conclusions

Within Nantucket Sound and adjacent waters, the development of an ecosystem-scale, scientifically based management strategy requires a formal and integrated examination of the existing and projected marine resources, ecosystem services, anthropogenic uses, and impacts. Having been managed in a fragmented manner has led to a sparse and disjointed understanding of the resources within these waters, further supporting the need for a unified management strategy.

Based on the results of a preliminary investigation, CCS supports the notion of state and federal coordination to manage these waters, using one, mutually acceptable management strategy that promotes the exchange of data between management groups. While the most direct means of achieving an ecosystem approach to management would be for the entirety of the Sound to be managed by one entity, such an agreement may be difficult to establish. The 1980 nomination by EOEA and the Attorney General of Nantucket Sound as a marine sanctuary outlined a novel, holistic approach to provide a united management regime for the Sound. However, the specific mechanics of implementation and maintenance under joint jurisdiction may have required further review. The proposed management and ultimate responsibility of the resulting sanctuary would reside with two separate entities, not meeting today's standards for national marine sanctuary and potentially complicating management processes. Regardless of its merits or shortcomings, no action was taken with respect to this nomination because NOAA did not have a program plan for the sanctuary system in place until 1983.

The fact that the state Legislature, the Executive Office of Environmental Affairs, the state Attorney General, and the National Marine Sanctuary resource evaluation committee have found that Nantucket Sound warrants increased environmental protection, possibly including sanctuary status, demonstrates a general consensus regarding the ecological, economic, recreational and aesthetic importance of that region. CCS found no evidence to support the position that the ecological significance of the Nantucket Sound region has been diminished since those proposals were made. Nantucket Sound remains a pristine and tremendously productive ecosystem worthy of environmental conservation and protection.

Despite past nominations' failure to gain national marine sanctuary status, experience shows that such a cooperative management arrangement may be achieved, as evidenced by the Channel Island National Marine Sanctuary in California and the Hawaiian Islands Humpback Whale National Marine Sanctuary. By defining bio-regions, these sanctuaries established management polygons based on scientific determination of contiguous marine ecosystems or functional habitat units that best served to protect, study and manage waters on an ecosystem-scale. This type of determination is very much aligned with NOAA's fundamental management philosophy for the sanctuary program that pledges "*an ecosystem approach to marine environmental protection.*" Given the new paradigm of broad-based, ecosystem-scale management in science and environment policy, CCS recommends that future management of the marine and coastal resources of Nantucket Sound begin with comprehensive ecological study. Once such a study is completed, a more thorough and effective management strategy can be developed to guide appropriate management and policy decisions for this important coastal resource.

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Appendix A   *Table 1*: Massachusetts Laws and Regulations

Resource/Issue	Applicable Legislation	Regulations	Agencies
Areas of Critical Environmental Concern	MGL c. 21A §2(7); St. 1974, c. 806 s. 40(e)	301 CMR 12.00	DEM
Coastal Development or Use	MGL c. 91; MGL c. 6A § 2-7 MGL c. 21A, s. 4A	310 CMR 9.00	DEP
		301 CMR 20.00-24.00	CZM
Dredging and Filling	MGL c. 21 § 26-35	310 CMR 9.00	DEP
Emergency Response/ Spill Reporting	MGL c. 21E (State Superfund Law)	310 CMR 40.0000 (Mass. Contingency Plan)	DEP
Endangered Species (Natural Heritage Program)	MGL c. 131 s. 23	321 CMR 10.00	DFW
Environmental Notification Forms/Impact Reports	MGL c. 30 §61-62H (Mass. Environmental Policy Act [MEPA])	301 CMR 11.00	EOEC
Historic Preservation	MGL c. 9 §26-27C	950 CMR 71.00	MHC
Marine Fisheries	MGL c. 130	322 CMR 1.00-12.00	DFW
Ocean Sanctuaries Act	M.G.L. c. 132A, §§ 13-16, 18	302 CMR 3.00	DEM
Scenic/ Recreational Rivers Orders	MGL c. 21A, s. 2(28)	302 CMR 3.00	DEM
Water Pollution Control	MGL c. 21 § 26-53 (Mass. Clean Waters Act)	257CMR 2.00 310 CMR 41.00 314 CMR 1.00 - 15.00 314 CMR 4.00 314 CMR 9.00	DEP
Waterways Licensing	MGL c. 91 (Public Waterfront Act)	310 CMR 9.00	DEP
Wetlands	MGL c. 131 s. 40 (Wetlands Protection Act)	310 CMR 10.00	DEP CCC

Key: CCC= Cape Cod Commission; CZM= Office of Coastal Zone Management; DEM= Dept. of Environmental Management; DEP= Dept. of Environmental Protection; DFW=Dept. of Fish and Wildlife and Environmental Law Enforcement; MHC= Mass. Historical Commission

Appendix A *Table 2*: Applicable Federal Laws

Resource/Issue	Applicable Legislation	Agencies
Atlantic Coastal Fisheries Cooperative Management Act	16 U.S.C. §§ 5101-5108	NOAA Atlantic States Marine Fisheries Commission
Coastal Zone Management Act	16 U.S.C. §§ 1451-1465	NOAA NERR CZM
Endangered Species Act	16 U.S.C. §§ 1531-1544	NOAA EOEA
Estuarine Areas Act	16 U.S.C. §§ 1221-1226	NOAA
Federal Water Pollution Control Act (Clean Water Act)	33 U.S.C. §§ 1251-1387	EPA
Magnuson-Stevens Fishery Conservation and Management Act	16 U.S.C. 1801-1882	NOAA
Marine Mammal Protection Act	16 U.S.C. §§ 1361-1421h	NOAA
Marine Protection, Research, and Sanctuaries Act (Marine Sanctuaries Act)	16 U.S.C. §§ 1431-1445a	NOAA
Migratory Bird Conservation Act	16 U.S.C. §§ 715-715r	Migratory Bird Conservation Commission
National Environmental Policy Act (NEPA)	42 U.S.C. §§ 4321-4347	Council on Environmental Quality Office of Environmental Quality
National Wildlife Refuge System Administration Act	16 U.S.C. §§ 668dd-668ee	FWS
Outer Continental Shelf Lands Act	43 U.S.C. §§ 1331-1356	DOI CZM

Key: CZM=Massachusetts CZM; DOI= Dept. of Interior; EPA= Environmental Protection Agency; FWS= U.S. Fish and Wildlife Service; NERR= National Estuarine Research Reserve; NOAA= National Oceanic and Atmospheric Administration

NOMINATION LETTER

for

a Marine Sanctuary in

Nantucket Sound

Pursuant to Title III of the Marine Protection, Research and

Sanctuaries Act of 1972

Prepared by:

Executive Office of Environmental Affairs
Massachusetts Coastal Zone Management
Department of Environmental Management
Division of Marine Fisheries

Office of the Attorney General

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Approved by: John Manton, Acting State Purchasing Agent

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I. INTRODUCTION

This nomination letter formally nominates the central portion of Nantucket Sound located outside of Massachusetts coastal waters as a marine sanctuary pursuant to Title III of the Marine Protection, Research and Sanctuaries Act of 1972. This nomination letter was prepared by the Massachusetts Executive Office of Environmental Affairs and the Massachusetts Attorney General's Office.

The Commonwealth of Massachusetts finds that Nantucket Sound contains distinctive ecological, recreational, historic and aesthetic resources that form the basis of the predominant economic pursuits of the area; fishing and tourism. Nantucket Sound is an important habitat area containing spawning, nursery and feeding grounds and migration routes for a number of the nation's important living animal resources, an area with a high biological productivity and diversity of species, and a premier marine-oriented recreational and historic area of regional and national significance.

The Massachusetts coastal waters of Nantucket Sound are now subject to a comprehensive regulatory scheme set forth in Massachusetts General Laws Chapter 132A, Sections 13-16 and 18 (The Ocean Sanctuary Act). This law establishes sanctuaries along the coastline of Massachusetts to protect these water bodies from any exploitation, development or activity that would seriously alter or otherwise endanger the ecology or the appearance of the ocean, the seabed or subsoil thereof or the Cape Cod National Seashore. These sanctuaries are under the care and control of the Department of Environmental Management within the Executive Office of Environmental Affairs. The Cape and Islands Ocean Sanctuary was established in 1972. It is the purpose of this nomination to insure that the valuable resources located in the central waters of the Sound are protected and enhanced just as the resources in the coastal waters are through the Cape and Islands State Ocean Sanctuary. The central waters of Nantucket Sound are nominated for their value as a habitat area, species area, unique area and a recreational and aesthetic area.

This sanctuary nomination proposes that the management of the Nantucket Sound Marine Sanctuary be delegated to the Massachusetts Executive Office of Environmental Affairs (EOEA). This Secretariat is responsible at the state level for the environmental management of the coastal waters and adjacent land areas of Nantucket Sound. It is appropriate that the agency responsible for managing the state Ocean Sanctuary, also manage a marine sanctuary for the central waters in the Sound and that the entirety of Nantucket Sound be subject to an integrated management scheme.

The Commonwealth further proposes that the scope and substance of the proposed Nantucket Sound Marine Sanctuary conform with the statutory standards currently existing for the Cape and Islands Ocean Sanctuary. Among the activities that are prohibited in the state Ocean Sanctuary are: the building of any structure on the seabed or under the subsoil; the construction or operation of offshore or floating electric generating stations; the removal of any minerals such as sand or gravel; the drilling for gas or oil; the dumping or discharge of any commercial or industrial wastes; municipal wastewater treatment discharge; commercial advertisement and the incineration of solid waste material or refuse on, or in, any vessel or boat of any size moored within the boundaries of the sanctuary.

II. AREA NOMINATED

This nomination letter formally nominates the central portion of Nantucket Sound that constitutes federal waters as a marine sanctuary pursuant to Title III of the Marine Protection, Research and Sanctuaries Act of 1972 to be managed by the Massachusetts Executive Office of Environmental Affairs.

A. General Description

The Nantucket Sound area contains numerous distinctive ecological, recreational, historic and aesthetic resources of regional and national significance. While the proposed marine sanctuary consists of the federal waters found in the central section of the Sound, these, the coastal waters and the surrounding land area of Cape Cod, Martha's Vineyard and Nantucket constitute one integrated ecosystem whose living resources use the entire Nantucket Sound area without knowledge or consideration of political boundaries. Activities occurring in federal waters directly impact Massachusetts coastal waters, estuaries and other shore areas and vice versa.

Located south of Cape Cod, Nantucket Sound lies in an area of convergence of two major ocean currents, the Laborador Current and the Gulf Stream. While the temperate waters of the Gulf Stream predominate, the mixture of these two water systems contributes to the large diversity of species found here. it is this diversity of species rather than the volume of biomass that is one of the distinguishing characteristics of this important resource area. Cape Cod represents the southern limit for many cold water species and the northern limit for warm water types. Marine mammals and bird colonies, attracted by the shallowness of the sound, avail themselves of these productive and protected waters for feeding and migratory habitats. The richness of this transition zone ecology enhances the stability of plant life and the productivity of the estuaries in bordering coastlands, that provide habitats for the many species that use the proposed marine sanctuary areas as nursery and feeding grounds.

Nantucket Sound is bordered by Cape Cod, Nantucket and Martha's Vineyard collectively forming one of the most popular summer resorts on the East Coast. The high quality of the Sound's water supports a multitude of recreational activities essential to a viable tourist industry. There is a physical and emotional attractiveness about the Cape and Islands which has appealed to tourists for decades. Boating, swimming, fishing and sightseeing enthusiasts have traditionally been lured by the Sound's excellent water and overall aesthetic quality. For Canada and other northern locations, the Nantucket Sound area is the shortest distance to a warm water beach. Sportfishermen benefit from the diversity of species in the Sound and consider the many shoals of Nantucket Sound as prime fishing spots. The Sound's reliable southwest breeze, picturesque harbors and good marine facilities make the location a mecca for recreational boating.

Cape Cod and the Islands contain a large number and variety of public beaches, parks, conservation and other recreational areas. The area's important tourist and recreational industry is dependent upon the continued protection and enhancement of the Sound's many distinctive natural resources.

The waters of Nantucket Sound also support the economically valuable commercial and recreational fisheries of the area. Finfish and shellfish resources are dependent on the Sound's oceanographic conditions and water quality. These fisheries have traditionally been a social and economic mainstay for many Cape and Island communities. Of the some 80 species found in Nantucket Sound, black seabass, scup, flounder, squid, blackfish, quahog and bay scallops are the predominate commercial fisheries. In addition to the species which have traditionally contributed to the fishery resource, there are varieties of finfish and shellfish in the Sound that are not now regularly taken by commercial fishermen. This potential fish supply could well contribute to the growth of the regional fishing industry through the development of underutilized species.

The Nantucket Sound area is of exceptional value for its contribution to the heritage of the United States. Nantucket Sound,Cape Cod and the Islands form an integral part of the maritime tradition of this country. Since the Revolutionary War period, Nantucket Sound has been the location of shipyards, served as a major shipping corridor and the home port for a large segment of America's fishing and coastal trading industry. During the nineteenth century, Nantucket was the leading whaling port in the world, sheltering a fleet of 65 vessels. Reflecting this tradition, the entire island of Nantucket was included in the National Register of Historic Landmarks in 1975. The nominated marine sanctuary area contains a number of shipwrecks that are of historic and educational value in interpreting the maritime history of America.

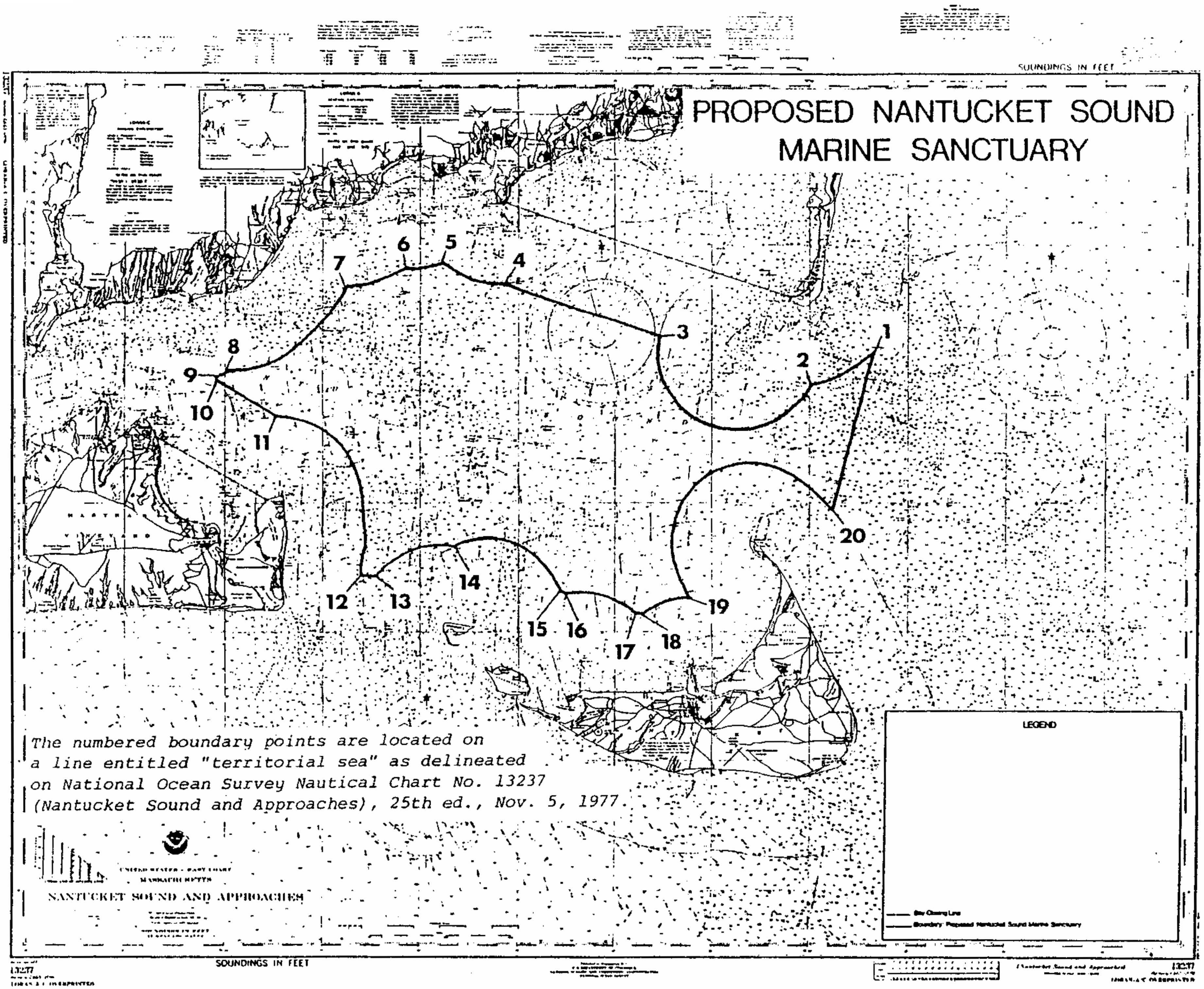
B. <u>Coordinates, Approximate Size and Boundaries</u>

As proposed, the Nantucket Sound Marine Sanctuary would include approximately 163 square nautical miles of water and seabed located between Cape Cod, Vineyard Sound, the islands of Martha's Vineyard and Nantucket extending seaward beyond

Monomoy and Nantucket Islands. The sanctuary would include all waters and seabed within Nantucket Sound outside the three mile limit, as measured from the mean low water line together with an area extending seaward three (3) geographic miles from a presently hypothetical line drawn between Monomoy and Nantucket Island and bounded on the north and south by the three mile seaward limits of state ownership, as set forth by the Memorandum of Settlement approved by the Special Master for the United States Supreme Court in proceedings supplementary to United States of America v. State of Maine, et al, October term, 1979.

The proposed boundaries are delineated in the map on figure 1 and the coordinates of which are listed in table 1.

The area proposed for a federal marine sanctuary consists of all the waters in Nantucket Sound that will come under federal jurisdiction should the above referenced settlement be consummated. As federal waters, this area would not be subject to regulation as part of the Massachusetts Cape and Islands Ocean Sanctuary. The absence of marine sanctuary protection for the federal waters in the center of the Sound would negate efforts by the Commonwealth of Massachusetts to insure the environmental protection of the marine resources of this important water body through its Ocean Sanctuary Program. Nantucket Sound must have a coordinated management regime as proposed in this nomination letter if the ecological, recreational, historic and aesthetic resources of the Sound are to be adequately protected.


PROPOSED NANTUCKET SOUND
MARINE SANCTUARY
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The numbered boundary points are located on
a line entitled "territorial sea" as delineated
on National Ocean Survey Nautical Chart No. 13237
(Nantucket Sound and Approaches), 25th ed., Nov. 5, 1977.
NANTUCKET SOUND AND APPROACHES
SOUNDINGS IN FEET
LEGEND

Figure 1.

Table 1. Boundaries of Nantucket Sound Marine Sancturay

	Latitude	Longitude
1.	41° 30' 42"	69° 56' 40"
2.	41° 29' 36"	70° 00' 00"
3.	41° 31' 25"	70° 07' 48"
4.	41° 33' 36"	70° 16' 00"
5.	41° 34' 24"	70° 18' 55"
6.	41° 34' 10"	70° 20' 43"
7.	41° 33' 20"	70° 23' 54"
8.	41° 30' 07"	70° 29' 50"
9.	41° 29' 54"	70° 30' 30"
10.	41° 29' 40"	70° 30' 18"
11.	41° 28' 22"	70° 27' 18"
12.	41° 22' 15"	70° 23' 03"
13.	41° 22' 12"	70° 22' 15"
14.	41° 23' 22"	70° 18' 15"
15.	41° 21' 38"	70° 12' 52"
16.	41° 21' 30"	70° 12' 30"
17.	41° 20' 45"	70° 09' 00"
18.	41° 20' 45"	70° 08' 36"
19.	41° 21' 24"	70° 06' 06"
20.	41° 24' 42"	69° 58' 48"

III. CHARACTERISTICS OF NANTUCKET SOUND

A. OCEANOGRAPHIC FEATURE

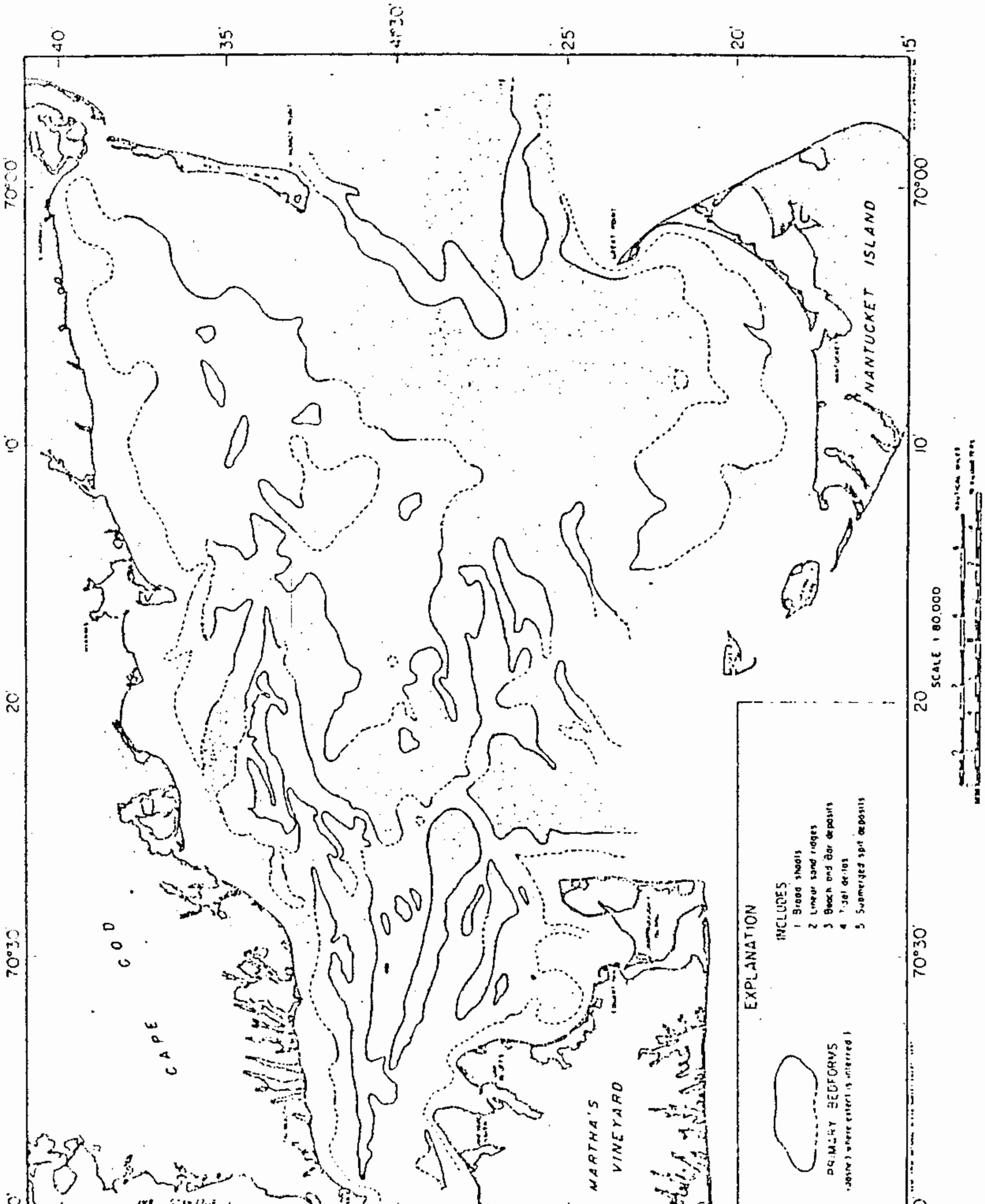
Two important oceanographic conditions in Nantucket Sound are the merging of two major ocean currents and the continous flood and ebb tide movement resulting in a continuous mixing of the waters throughout the Sound area. Worldwide, there are few coastal areas where two major marine ecosystems meet and Nantucket Sound is part of one such area. The confluence of the Laborador Current and the Gulfstream create a dynamic and highly diverse marine environment. The Sound's daily flood and ebb of water help create a highly productive ecosystem by insuring that the waters are thoroughly mixed on a continuous basis. This continuous mixing of the waters circulates nutrients throughout the entire Sound area from the many productive estuaries on Cape Cod and the islands.

There are three major tidal entrances to Nantucket Sound which are responsible for the good circulation in this water body. These are Vineyard Sound between Martha's Vineyard, Woods Hole and the Elizabeth Islands, Pollock Rip Channel between Monomoy Island and Great Point on Nantucket, and Muskeget Channel between Muskeget Island and Martha's Vineyard.

In general, the tidal currents move eastward during flood stages and westward during ebb stages. Average spring tidal velocities at selected stations in each entrance were plotted from National Oceanographic Service current data (1980) in order to further characterize these areas. Summarization of the time/velocity data indicate the following:

1) maximum velocities during both stages and the time at which peak velocities occur define a symmetrical tide curve for each station;
2) maximum current velocities differ between stations (i.e., Pollock Rip Channel 1.5 kts. Vineyard Sound 3 kts. and Muskeget Cahnnel 4 kts.); and,
3) there is a temporal difference in tidal response between stations. Based on Pollock Rip Channel, tides occur 0.5 hours later in

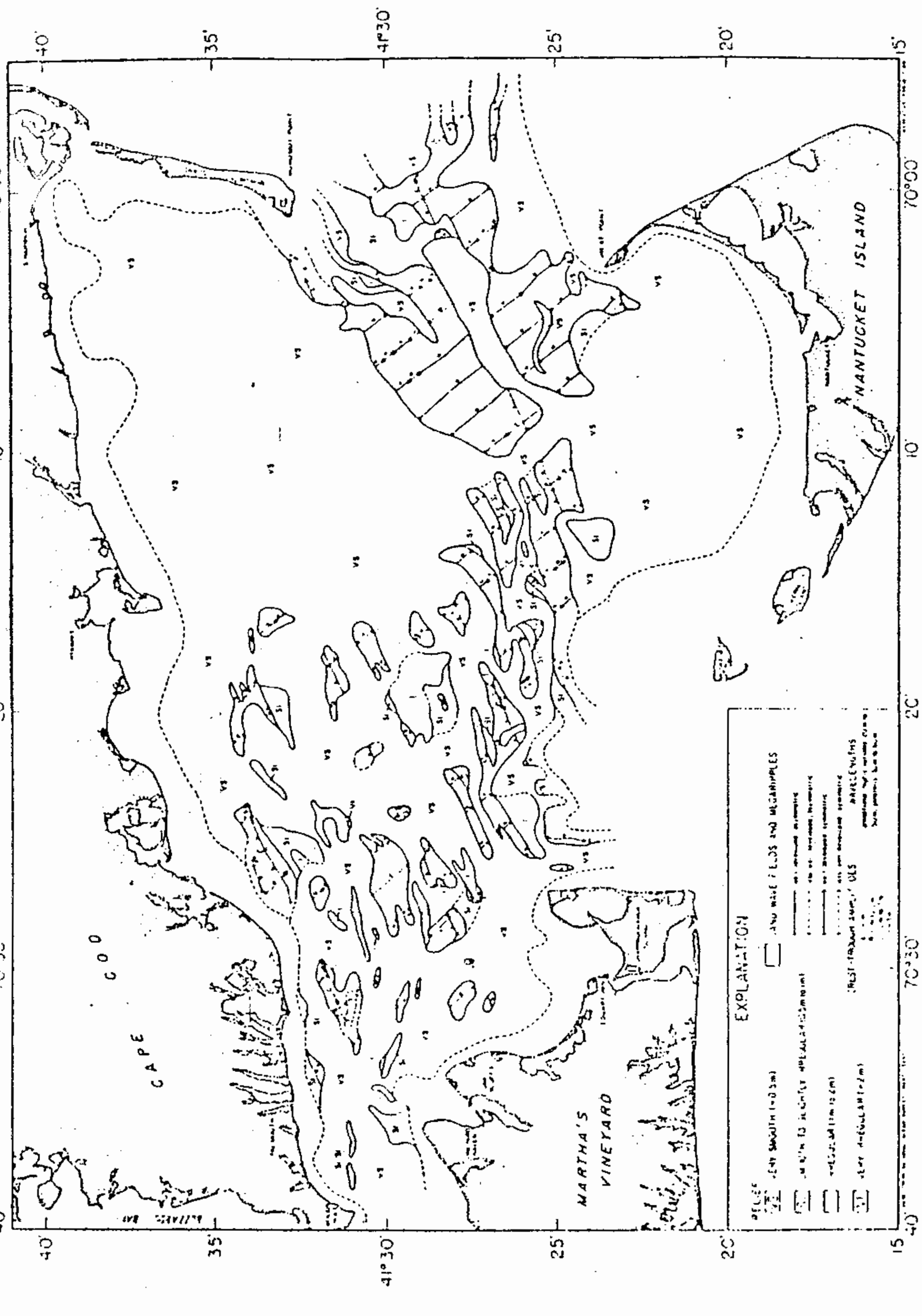
O, Hara, C.J., "Bedform Morphology", 1980



MAP SHOWING DISTRIBUTION OF PRIMARY BEDFORMS

by Charles J. O'Hara 1980

O, Hara, C.J., "Bedform Morphology", 1980



MAP SHOWING SEAFLOOR MICROTOPOGRAPHY
by
Charles J. O'Hara
1980

Muskeget Channel and 1.5 hours later in Vineyard Sound.

B. Seafloor Topography

All of Nantucket Sound, and the landbodies of Martha's Vineyard and Nantucket comprise an area at or above the 20 meter (65 feet) offshore contour and can be considered as one contiguous geological unit. The deposition of outwash plain material over the coastal plain deposits are responsible for the unusually shallow water depth throughout the Sound. Average depths are only on the order of 10 - 15 (30 - 50 feet) meters. The bottom topography of Nantucket Sound has been mapped (O'Hara, 1980) as three (3) bedform units. First are the primary bedforms covering over 50 - 60% of the Sound. These are very large features which include: 1) broad shoals, 2) linear sand ridges, 3) beach and bar deposits, 4) tidal deltas, and 5) submerged spit deposits. It appears as though most of the primary bedforms are composed of moderate to well sorted, medium to coarse sands with small percentages of gravel. The largest of these bedforms are the sand ridges, some of which are 20 kilometers (12.4 miles) long, 3 kilometers (1.9 miles) wide and 13 meters (46 feet) thick.

Superimposed on the primary bedforms are secondary bedforms. These are very well developed sand waves, 1 to 4 meters in height, and megaripples, less than 1 meter (3.5 feet) in height. The existence of these features indicates that the larger primary bedforms are mobile and that they form and/or migrate in response to tidal currents. Active sand bodies are found throughout the center of the Sound from Vineyard Sound eastward to the Atlantic Ocean. The most significant area of bedform activity is located between Monomoy Island and Great Point at the eastern entrance to Nantucket Sound from the Atlantic Ocean.

The last of the bedform units are the swales and interridge lows which occur between the larger primary bedforms. Generally, the swales and lows are very flat surfaces representing either areas undergoing scour as in western portions of the Sound, or, sediment sinks in which very fine sediments are being deposited under low energy "quiet water" conditions. The latter appears to be representative of the northeastern Sound area where tidal currents have very low velocity peak flows. An important geotechnical feature of the swale unit sediment, is highly unstable organic gas-charged muds which are often present.

C. WEATHER CONDITIONS

General wind conditions for the Sound are summarized from data collected on Nantucket. The eight year record documents the year-round wind duration, average speed, and maximum intensities. Winds from the WSW (west-southwest) and SW (southwest) have the greatest duration and therefore can be considered the prevailing winds. Average wind speeds are quite similar from all compass directions and range between 12 and 14 mph. Winds from the NNE (north northeast) have an average speed greater than 14 mph. probably as a result of the maximum winds which occur during winter. The NNE winds have the greatest occurrence of speeds over 32 mph and therefore are the dominant winds, in spite of their short duration.

D. WATER QUALITY

All the tidal waters in Nantucket Sound with the exception of Hyannis, Falmouth and Nantucket inner harbor basins are classified as SA under the Massachusetts Water Quality Standards.

Class SA is the highest class for coastal and marine waters. Waters assigned to this class are designated for the uses of protection and propagation fo fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting without depuration in approved areas.

The specified levels of certain parameters of water classified as SA is as follows:

1) Dissolved Oxygen: not less than 6.5 mg/l; ph: 6.8 - 8.5
2) Coliform Bacteria: not to exceed a median value of 70 and not more than 10% of samples over 230

3) Chemical Constituents: none in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other use.

Special antidegradation provisions exist for those waters of Nantucket Sound whose quality is or becomes consistently higher than that quality necessary to sustain the national goals. The water quality shall be maintained at that higher level unless limited degradation is authorized by the Massachusetts Division of Water Pollution Control.

E. SHORELINE HABITAT VALUE AND DIVERSITY

The shorelines of Cape Cod, Monomoy Island, Nantucket, Ester Island, Tuckernut Island, Muskeget Island, and Martha's Vineyard border on Nantucket Sound and comprise over 100 statue miles of an open-coast environment. This extensive system of salt ponds, salt marshes, estuaries and embayments provide irreplaceable habitats for many of the marine and shore birds and fisheries that utilize the proposed sanctuary area as a feeding and migratory habitat. This system also provides large quanities of nutrients to the marine food chain of the Sound, thus significantly contributing to the productivity of this ecosystem.

The barrier beaches located at the entrances to these coastal waterbodies provide habitats for nesting and migratory birds and other wildlife and are the sites of most of the public beaches in the Nantucket Sound area.

The coastal wetlands resources along the southern shore of Cape Cod have been mapped by the Department of Environmental Management (EOEA) with the use of aerial photography taken in the Spring of 1978. This mapping identified over 2500 acres of salt marsh, 39 coastal water bodies and 22 barrier beaches along this section of coast. Nantucket and Martha's Vineyard also contain productive estuaries and embayments that are important to the continued productivity of the Nantucket Sound area.

The Massachusetts Legislature adopted the Coastal Wetlands Act to promote the public safety, health and welfare, to protect public and private property and to protect wildlife and marine fisheries by restricting certain land uses. This form of wetland protection is accomplished by placing a restriction order on the property deed of the land owner. Recognizing the importance of the coastal wetlands in the Nantucket Sound area, wetland restriction orders have been signed for the Cape Cod towns facing the Sound and the coastal wetland restrictions program will be completed for Nantucket and Martha's Vineyard in 1981.

Table 2. Distribution and Diversity of Habitats Along Nantucket Sound Coast of Cape Cod Critically Important to Wildlife and Marine Fisheries

Town	Salt Marsh Acreage	Water Bodies(1)	Barrier Beaches
Falmouth	215	11	7
Mashpee	230	5	3
Barnstable	575	7	7
Yarmouth	310	3	2
Dennis	295	4	1
Harwich	420	4	0
Chatham	470	5	2
Total	2,515	39	22

(1) Includes salt ponds, harbors, bays, rivers, and estuaries connected to Nantucket Sound. (Wetlands Restriction Program, DEM (EOEA).

The Connamessett River, Childs River, Quasket River, Mashpee River, Santuit River, Marstons Mills River, Centerville River, Mill Creek, Parker River, Bass River, Herring River, Andrews River, Mill Pond, Frostfish Creek, and Muddy Creek on Cape Cod are active anadramous fish runs for the alewive.

The land areas adjoining the Sound contain a number of important wildlife refuges. These refuges compliment the extensive areas of shallow water within the nominated area that provide feeding habitat for the bird species that utilize the refuges.

F. IMPORTANT ANIMAL AND PLANT LIFE

1. Finfish

The section of Nantucket Sound nominated as a marine sanctuary is an important species habitat containing spawning, breeding, nursery and feeding grounds for many shellfish and finfish species. In this transition zone species from two distinct systems come together to form a richly diverse and productive biota.

Over 79 different finfish and shellfish have been captured in bottom trawl surveys conducted by the Massachusetts Division of Marine Fisheries in Nantucket Sound between 1974 and 1980. (See Appendix I). The Division initiated a more comprehensive bottom trawl survey program in 1978 to monitor the relative abundance of fish stocks in Massachusetts coastal waters using a Yankee Otter Trawl, size 20. In Nantucket Sound, the surveys included both coastal waters and waters in the nominated area. The ten most predominant species by weight per tow and number per tow in Nantucket Sound for both spring and autumn bottom trawl surveys in 1978 are listed in appendix 2. The species composition and relative abundance changed little between 1978 and 1979, indicating that this is an accurate listing of the predominate fish of the Sound.

These annual Fishery Resource Assessments also document the importance of Nantucket Sound as a spawning and nursery ground for many valuable commercial and recreational species and other species important in the food chain. The spring bottom trawl catches consisted primarily of mature fish approaching spawning conditions. The autumn trawl survey results showed an abundance of one year olds as well as large numbers of young-of-the-year fish.

The following is a brief discussion of the predominant species of finfish and shellfish that utilize Nantucket Sound as a breeding, spawning or nursery habitat:

American sand lance (Ammodytes americansus) is a coastal species commonly found in the mouths of estuaries and along sandy bottoms. Spawning is believed to occur in late winter in Massachusetts from eggs broadcasted on sandy bottoms in water up to 20m deep. Sand lance are taken for bait fisheries. Various sport fishes, including cod, striped bass and bluefish as well as sea birds and whales are heavily dependent on this finfish species for food.

Black sea bass (*Centropristis striata*) is an important sport fish that is also taken commercially by pot and otter trawl. The Stock Resource Assessment conducted by the Division of Marine Fisheries found spring catches to consist of pre-spawning adults. 99% of black sea bass in autumn tows consisted of young-of-the-year fish as well as possibly age 1 fish. In Massachusetts waters, this species is most common in Nantucket Sound.

Butterfish (*Peprilus triacanthus*) spawn a few miles out to sea (including Nantucket Sound) in the summer months. During the fall, butterfish are a predominant species in Nantucket Sound and found in nearly all depth strata.

Little Skate (*Raja erinacea*) is a common species in Nantucket Sound. This species has no defined spawning site. Eggs are found throughout the Sound, being most abundant in the spring. While this species has little commercial or recreational value, it is an important component in the Nantucket Sound marine community.

Longhorn Sculpin (*Myoxocephalus octodecemspinosus*) is another common species in Nantucket Sound that spawns nearshore during winter and early spring. It is believed that the longhorn sculpin moves to deeper waters in late spring and returns shoreward in the late autumn.

Menhaden (*Brevoortia tyrannus*) range from Nova Scotia to Florida and occur in estuarine waters as eggs, larvae, juveniles and adults. Menhaden spawn in nearshore waters during late spring and summer. Juveniles enter the estuaries of Nantucket Sound in late winter and early spring and remain in these environments for 6 to 8 months before leaving for its southern range in early fall. This species is food of the striped bass, bluefish, summer flounder and weakfish. Menhaden is an important commercial species used for fish bait, fish oil, meal and solubles.

Northern searobin (Prionotus carolinus) is one of the most abundant finfish species in Nantucket Sound. It spawns from June to September in the shoal water and estuaries of the Sound. The northern searobin is taken by commercial and recreational fishermen and is increasing in importance as an underutilized species.

Scup (Stenotomus chrysops)is a species of the continental shelf of eastern North America occurring regularly from Cape Hatteras to Cape Cod. This species is a summer and early fall resident of southern Massachusetts coastal waters when it comes inshore to spawn. Scup are an important link in the food chain. They are predominantly bottom feeders and are in turn eaten by fish such as cod and bluefish. It is an important foodfish species to draggermen, trap fisherman and sport fishermen. Division of Marine Fisheries Resource Stock Assessments during 1978 and 1979, found that while scup were rarely found in the bottom trawl north of Cape Cod, they ranked No. 2 in weight and number during the spring bottom trawl survey and No. 1 in the autumn survey in Nantucket Sound.

Tautog or blackfish (Tautoga onitis) represents a prominent member of inshore benthic community and are usually taken on rocky bottoms or near pilings, jetties and any bottom irregularly. In Massachusetts waters, this species is most abundant south of Cape Cod in the immediate vicinity of the coast (less than 60 feet depth). They spawn from May to August in weedy inshore areas of the Sound. The tautog represents an important resource for Massachusetts as a recreational fish. Sport catches are abundant from May through September.

Windowpane (Scophthalmus aquosus) is a common species of Massachusetts coastal waters and is predominantly abundant in Nantucket Sound in the spring. Also, the greatest number of large fish of this species found in Massachusetts waters occur in Nantucket Sound. Spawning is during spring and fall. The windowpane is a very-thin bodied flounder and while not attractive as a commercial or recreational fish, it serves an important role in the marine food chain.

2. Shellfish

Longfin Squid (Loligo pealei) is a very important species in the marine food chain. It is prolific, rapid growing and short lived. This species remains the object of offshore pelagic trawl fisheries and is of increasing interest to inshore draggermen and trap operators. In the spring, they are concentrated in shoal waters south of Cape Cod, where spawning occurs. The Division of Marine Fisheries stock assessment surveys document Nantucket Sound as a nursery for this species.

Bay Scallop (Aequipecten irradians) is the most common and commercially valuable shelifish species found in the Nantucket Sound area. It spawn and makes habitat of flats exposed at lowest tides and subtidally on the shoals of Nantucket Sound.

Hard-shelled clam or Quahog (Mercenia) is very abundant in Nantucket Sound ranging in depths of two to forty feet. This species is very important commercially and is marketed as littleneck, cherrystone and hard shell clams.

American lobster (Homarus americanus) is found in the nominated area. Lobster larvae hatch in the summer and remain planktonic, drifting in near-surface currents for 10-30 days before settling to the bottom.

Atlantic deep sea scallop (Placopecten magellanicus) is found in limited quantities in Nantucket Sound in depths greater than 20 feet. This species spawns in late September and early October and utilizes these waters as a permanent habitat.

3. Marine Mammals

The waters of Nantucket Sound support several marine mammal populations either as occassional migrants or as permanent residents. Of these, the grey seal (Halichoerus grypus) is the most permanent and perhaps most unique. The grey seal ranges from Western Europe across the North Atlantic to Iceland and Canada. Muskeget Island, located in coastal waters of Nantucket Sound adjoining the nominated area, harbors the southern most breeding population in the world and the only one known in the United States. While the current population consists of one or two dozen individuals, historically it was larger containing up to as many as 50 seals two decades ago. This species of seals breed, pup and feed in an area roughly seven miles by three miles surrounding Tuckernuck and Muskeget Islands. Grey seals have been sighted in all months of the year. In 1980, approximately nineteen individuals were signed on Muskeget and the adjacent sand spits, and in 1978 sightings were reported on Bigelow Point, Tuckernuck Island and off of Nantucket at Scasconset.

The harbor seal (Phoca vitulina) ranges from Labrador to Rhode Island and is an inshore resident of bays and sounds, breeding, sunning and resting on tidal ledges and sand shoals. A small population (in the hundreds) of harbor seals uses Nantucket Sound as an annual resident winter habitat. Their haul out points include Monomoy Island, a barrier island on the eastern end of the Sound and other islands and sand spits in the Sound.

Different species of whales use the offshore waters as a migratory passage between northern summering grounds and southern wintering grounds. Right, humpback and pilot whales occassionally pass through Nantucket Sound. The right whale (Eubalaena glacialis), classified as endangered by the U.S. Fish and Wildlife Service, has been sighted west of Nantucket Sound in Vineyard Sound off of Quick's Hole in 1958, off of Menemsha Bight (Martha's Vineyard) for 4 consecutive days during the same year and once in 1959. This species was sighted off of Squash Meadow Shoal in Nantucket Sound in 1959. There were two possible sightings in Nantucket Sound in the summer of 1979 and one definite sighting in 1978 of the humpback whale (Legapteria movaeangliae). The pilot whale (Globicephala melaena) has been sighted in Nantucket Sound in 1979 and 1980. These, the finback whale (Balaenoptera physalus) and possibly other species of whales are seen more frequently off of Little and Great Round Shoals to feed on invertebrates and fish that are abundant in this area. Portions of these shoals lie on the eastern boundary of the nominated marine sanctuary area.

There are four species of sea turtles that are found in Nantucket Sound; the green turtle, (Chelonia mydas), Kemp's ridley (Lepidochelys Kemplli), the leatherback (Dermochelys coriacea) and the diamondback terrapin (Melaclemys terrapin terrapin).

The green turtle is a highly migratory species that breed and nest in tropical waters. The young hatchings leave for more northern waters where they feed as carnivores until they reach maturity. One of the few places in New England where concentrations of young greens are found is Nantucket Sound. The species was once the most numerous of sea turtles, but it has been systematically extirpated in habitat after habitat by human predators in search of the green turtle's economically valuable meat and colipee. The green turtle is now listed as a federally threatened species and has state endangered status in Massachusetts.

The leatherback is another migratory species that is currently on the Federal Endangered Species List. The leatherback's population has been seriously depleted from egg collection on nesting beaches and high mortality from ingesting toxic or indigestible objects. Concentrations of leatherback turtles are found in Massachusetts waters during the summer and autumn months, particularly in the waters south of Cape Cod.

The Kemp's ridley or the Atlantic ridley nests on the Gulf coast of Mexico with the young carnivorous turtles migrating north during the summer months. Survival during the ridley's juvenile stage in New England waters is critical to the continued existence of this species. The ridley turtle concentrates in Massachusetts waters from July through November in shallow waters adjacent to Cape Cod including Nantucket Sound. This species is on the Federal Endangered Species List and its population had dropped from 250,000 in the 1940's to a current figure of less than 3,000.

The diamondback terrapin's northernmost breeding habitat is on the shores of Cape Cod. In the Nantucket Sound area, this species is found in Pleasant Bay, (Chatham) and Washburn Island (Falmouth) where they nest in the sand dunes.

Muskeget Island is the only known habitat of the Muskeget role (Microtus breweri). While not a marine mammal, this species' only occurrence is on a low-lying island in Nantucket Sound and would be susceptible to a large scale degradation of the waters of the Sound.

4. Bird Populations

The Nantucket Sound area is of regional and national importance as a breeding, nesting, resting and feeding bird habitat. The Sound's ecosystem containing clean water, large productive estuaries, extensive shallow shoal areas, thousands of acres of salt marsh and long stretches of undeveloped beaches attract and provide ideal habitats for vast migratory and resident bird populations.

The Monomoy National Wildlife Refuge illustrates the productivity of the many bird refuges and other habitat areas not officially designated in Nantucket Sound. This wildlife refuge is located on Monomoy and Morris Islands separating the Atlantic Ocean from Nantucket Sound and consists of sand dunes, salt and fresh water marshes, fresh water ponds and beaches. More than 300 species of birds have been recorded on the refuge including nesting waterfowl, gulls and terns. The refuge is an important nesting habitat for waterfowl, breeding habitat for a number of species and a heavily used migratory habitat for shore birds.

Nantucket Sound lies within the Atlantic Flyway, one of four major migratory routes used by North American waterfowl. Vast numbers of birds use the salt marshes, estuaries, shoals and nearshore areas as resting and feeding areas during spring and fall migration. The nominated area which includes portions of Little Round and Great Round shoals east of Monomoy Island serves as part of the largest winter habitat for waterfowl on the east coast of the United States. Significant percentage of the total east coast population of some species congregate in the Sound area. Common eiders (Somateria mollissima) and different types of scoters, including the black scoter (Melavitta nigra) and the surf scoter (M. perspicillata) are found during the fall and winter in the hundreds of thousands in the offshore shoal areas east of Monomoy Island. The extensive acreage of salt marsh in the Nantucket Sound area provide habitat for numerous species of marsh birds such as the herons, egrets and rails.

Many species of shorebirds use the beaches, dunes and tidal flats of Nantucket Sound area as nesting and feeding areas during the summer months.

Terns are abundant in the coastal zone and the individual species that breed in Massachusetts include the common tern (Sterna hirundo), beast tern (S. albifrons), roseate tern (S. dougallii), and the arctic tern (S. paradisaea). Active colonies presently exist along the shore of Nantucket Sound including Monomoy Island, Dennis, West Yarmouth and Nantucket. The arctic tern is at the southernmost extent of its range and this species and the roseate tern is uncommon in Massachusetts.

5. Rare and Endangered Marine Plants

Several rare plant species have documented occurrences in the coastlands bordering on Nantucket Sound. The most notable of these is the seabeach knotweed (Polygonium glaucum). The plant is rare in Massachusetts, with only peripheral distribution here at the northernmost edge of its range. Nantucket contains several viable colonies of seabeach knotweed on beach areas where the dunes are accreting. In 1980, colonies were located on Great Point, Coskata, east of Tom Nevers, and on Eel Point. A colony was reported on Coatue Point in 1978.

Historical sitings have been recorded in the Nantucket Sound area for the golden club (Orontium aquaticum), bristly foxtail (Setaria geniculata) and an alkali grass (Puccinallia paupercula, var. alaskana). While there have been no recent recorded sitings, it is possible that these plants still exist in undisturbed habitats along the coastal fringe of the Sound.

D. CONSERVATION AND RECREATIONAL RESOURCES

Federal, state and local governments and non-profit organizations have long recognized the unique natural resource value of the Nantucket Sound area and the need to protect these resources for conservation and recreation purposes. As a result, a large percentage of the land on Cape Cod and the islands is dedicated to conservation, open space and recreational uses. In the communities facing Nantucket Sound, there are approximately 1,750 acres of municipal recreation and conservation land, 56 acres of state land, 2,738 acres of federal land and 2,400 acres held by semi-public agencies.

Some of the important conservation and recreational facilities in the Nantucket Sound area that the proposed marine sanctuary would complement are listed in the following table:

FEDERAL

Name	Location	Size in Acres	Type
Cape Cod National Seashore	Lower Cape	25,000	recreational conservation
Monomoy National Wilderness Area	Chatham	2,698	conservation
Muskeget Island Wilderness Site	Nantucket Sound	230	wildlife refuge
Nantucket Island National Historic Landmark	Nantucket	entire island 50 square miles	historic preservation district

STATE

Name	Location	Size in Acres	Type
Nickerson State Park	Brewster	1,779	recreation
Martha's Vineyard State Forest	W. Tisbury Edgartown	4,000	recreation
Nantucket State Forest	Nantucket	137	conservation
Waquoit Bay Area of Critical Env. Concern	Falmouth Mashpee	1,213	environmental protection

PRIVATE NON-PROFIT

The Trustess of Reservations

Name	Location	Size in Acres	Type
Mashpee River	Mashpee	375	natural trout stream
Coskata-Coatue Wildlife Refuge	Nantucket	810	refuge
Great Point	Nantucket	42	refuge
Wasque Reservation	Martha's Vineyard	200	refuge
Menemsha Hills	Martha's Vineyard	120	refuge
Cape Poge Wildlife	Martha's Vineyard	428	refuge

Massachusetts Audubon Society (cont.):

Name	Location	Size in Acres	Type
Tern Island	Chatham	10	refuge
Felix Neck Wildlife Sanctuary	Edgartown	200	refuge
Salt Pond	Falmouth	117	refuge
Wells Land	Cotuit	1/3	refuge
Popponesset Sand Spit	Barnstable/Mashpee	50	refuge
Dead Neck/Sampson's	Cotuit	15	refuge

The establishment of a marine sanctuary in Nantucket Sound would be an important step in protecting and enhancing the extensive system of conservation and recreational areas in Nantucket Sound. Many of these areas are directly dependent upon the continued high quality of the waters of Nantucket Sound and any serious degradation of these waters would have a direct adverse impact on such areas.

E. UNIQUE HISTORIC FEATURES

Nantucket Sound has played an important role in the history of the United States. Cape Cod and the islands were inhabitated by American Indians centuries before the arrival of the first European explorers in the first decade of the seventeenth century (Champlain 1605, Gosnold 1605, Hudson 1609 and Smith 1614).

The early European settlers were initially attracted by the broad stands of timber, but gradually turned to fishing and other maritime pursuits for their livelihood. Shipyards were established in the harbors (Osterville, Coquit, Hyannis, Waquoit Bay and Bass River) and an active fishing and coastal trading industry developed in the Sound.

During the eighteenth and nineteenth centuries, Nantucket Sound served as a major corridor of coastal shipping between the Mid-Atlantic states and New England. The vessels carried coal, lumber, cobblestones and ice. They used Nantucket Sound as it was a protected corridor and to avoid the many shoals south and southwest of Nantucket. However, Nantucket Sound proved to be as dangerous as the shoals to the south Shifting shoals, poor navigational aides, sudden fogs, and storms caused many ships to founder while trying to navigate this water body. A number of these wrecks are located within or in waters adjacent to the nominated area. For example, the following is a list of reported wrecks on Long Shoal and Tuckernuck Shoal; only two of the many shoals in the nominated area.

Long Shoal is located entirely and Tuckernuck partially within the proposed marine sanctuary.

Long Shoal

Schooner Enterprise - 1896
Schooner Evolution - 1921
Schooner Richard S. Leaming - 1904
Schooner Sarah Woodbridge - 1859
Ship Seniranmis - 1803
Schooner Victory - 1821
Schooner French Van Guilder - 1885
Schooner Alice M. Lawrence - 1914
Ga. S F/V Shenandoah - 1912
Schooner Unique - 1917
Schooner Laura Annie Barnes - 1939

Tuckernuck Shoal

Schooner Addison - 1844
Schooner Champion - 1864
Schooner Emma G. Edwards - 1879
Schooner Elvya - 1836
Schooner L.B. Myers - 1863
Brig. Madison - 1853
Brig. Mary - 1802
Schooner Mary George - 1851
Schooner Mary Louise - 1876
Schooner Meridan - 1845
Schooner Orb - 1841
Schooner Rebecca Fogg - 1853
Ship Shooting Star - 1859
Schooner Splendid - 1856
Schooner Union - 1878
Schooner Warsaw - 1837
Schooner William Capes - 1876

These shipwrecks are important examples of the different types and styles of ship construction. As the techniques for successfully excavating and salvaging wooden shipwrecks develop, the historic and educational value of these and other wrecks in the nominated area for interpreting American maritime history will be enhanced.

A number of maritime related structures and sites facing Nantucket Sound have been included in the National Register of Historic Landmarks. These include the Wianno Club, the Chatham Windmill and the Monomoy Point Lighthouse on Cape Cod, the Edgartown, Cape Pogue, East Chop and West Chop Lighthouses, the entire island of Nantucket and the Wesleyan Grove National Register Historic District (including 300 sites and structures) on Martha's Vineyard.

F. SPECIAL AREA PLANNING PROGRAMS

1. Martha's Vineyard Commission

In 1974, the Massachusetts Legislature in recognition of the unique qualities of Martha's Vineyard, created the Martha's Vineyard Commisstion to: "...preserve and conserve for the enjoyment of present and future generations the unique natural, historical, ecological, scientific and cultural values of Martha's Vineyard which contribute to public enjoyment, inspiration and scientific study and to protect these values from development and uses which would impair them and to promote the enhancement of sound local economies",(Chapter 637 of laws of 1974).

2. Areas of Critical Environmental Concern

Waquoit Bay in Falmouth and Mashpee on Cape Cod has been designated an Area of Critical Environmental Concern pursuant to Massachusetts General Laws, Chapter 21A, section 2(7) and Popponesset Bay located in the Town of Mashpee was proposed for such a designation in the Massachusetts Coastal Zone Management Plan. ACECs are significant natural resource systems unique for their high natural productivity of known spawning grounds; shellfish beds; anadromous fish runs; feeding and breeding areas for waterfowl and birds dependent on coastal resources; habitat areas for threatened and endangered species and/or high water quality or potential to meet highest water quality standards. The basic function of an ACEC designation is to provide for a more thorough environmental review of state funded or state permitted projects, to coordinate and focus state environmental programs with federal programs and to encourage all levels of government to act consistently within the boundaries of ACECs.

Waquoit Bay is an extensive natural resource system which perhaps best typifies the many important estuarine systems forming a part of the Nantucket Sound ecosystem. This area's natural features include an undeveloped barrier beach, 330 acres of highly productive saltmarsh; economically important quahog, bay scallop and soft shelled clam shellfish beds whose harvest in 1977 exceeded $100,000; an alewive anadromous fish run; a great diversity of estuarine finfish species and important feeding and breeding grounds for many species of birds.

IV. DESCRIPTION OF PRESENT USES OF NANTUCKET SOUND

The major present uses of Nantuckt Sound are commercial fin and shell fishing, recreational fishing and boating and other marine related recreational activities.

A. Commercial Fisheries

Commercially important finfish found within the nominated area include Black seabass, butterfish, bluefish, cod, flounders, scup, striped bass, and tautog. The Massachusetts landings in 1979 for Barnstable and Dukes (Martha's Vineyard) County ports is shown in the table below. These fish were caught within the nominated area as well as in other locations. They are included to indicate the relative size and dollar value of these commercial species in this section of Massachusetts. The weights of fish given in this table are those or the fresh fish landed and the values are those received by the fishermen.

1979 Landings for Barnstable and Dukes County Ports

	Barnstable		Dukes	
	lbs.	$	lbs.	$
Finfish				
Alewife	185	80	8,260	295
Bluefish	177,189	40,736	57,431	15,341
Cod (drawn	491,770	161,029	5,905	2,290
Flounders				
Blackback	21,601	7,096	20,245	6,499
Dab, sea	521	230	851	171
Fluke	2,464	1,025	40,124	30,153
Scup	4,888	1,274	1,381	366
Striped Bass	93,078	94,692	27,227	26,308
Tautog	3,000	383	7,475	1,336
TOTAL	794,696	$306,545	168,899	$ 82,759

(NFMS- Massachusetts Landings- January-December 1979-)

Quahogs, bay and sea scallops, longfin squid and lobsters are shellfish species harvested commercially within the nominated area. These species are an important component of this regionally viable industry. The following table shows the size and dollar value of the 1979 landings for shellfish in the ports of Barnstable and Dukes (Martha's Vineyard) counties:

1979 Landings for Barnstable and Duke's County Ports

	Barnstable County		Dukes County	
	lbs	$	lbs	$
Shellfish				
Clams				
hard (meats)	153,747	479,223	56,017	150,545
soft (meats)	30,127	63,472	13,455	33,978
surf (meats)	1,340	1,852	3,681	3,802
Whelk (meats)	20,961	22,589	730	625
Scallops				
bay (meats)	39.957	164,979	219,566	846,196
sea (meats)	78,114	253,290	560	1,949
Squid	183	68	2,166	690
TOTAL	324,429	$ 985,473	296,175	$1,037,785

(NMFS-Massachusetts Landings- January to December, 1979)

Channeled Whelk (Busycon canaliculatam) fishery has recently become active in various sections of Nantucket Sound including portions of the nominated area near Horseshoe Shoals. This species is captured in shallow water on sandy bottoms. Surf clam (Spisula solidissums), soft shell clam (Mya arenaria) and oysters (Crassostrea virginica) are shellfish species harvested in the coastal waters of Nantucket Sound.

B. RECREATIONAL FISHERIES

Nantucket Sound contains a productive and diverse recreational fishery attracting fishermen from all over the country. Atlantic cod, bluefish, fluke, longhorn scuplin, sea robin, scup, striped bass, tautog, white perch and winter flounder are species found throughout the area being proposed as a marine sanctuary. The striped bass, bluefish, flounder, cod and scup are among the most popular species of the sportsfishermen in this area. There are over 30 boat launching ramps on Cape Cod and the islands and the Division of Marine Fisheries conservatively estimates that on a good summer day there are at least 200 rod and reel fishing boats utilizing Nantucket Sound. Shore fishermen are present during all seasons, while sports fishermen using boats confine their activities to the months of May through October.

A survey of sports fishermen conducted in 1975 by the Massachusetts Division of Marine Fisheries indicates that out-of-state fishermen make up 15% of the total marine recreational anglers fishing Massachusetts waters. The percentage of out-of-state anglers fishing Nantucket Sound waters was approximately 18%, Nantucket waters 86% and Martha's Vineyard waters 31%. Of the 18% out-of-state fishermen, 17% from New Jersey, 10% from Rhode Island, 7% from Delaware, 2% from Maine and the remaining 15% from other states of the Union. From the results of this survey, the Division estimates that there were approximately 100,000 outings by sportfishermen in the Nantucket Sound area in 1975.

Nantucket and Martha's Vineyard host two nationally known tournaments, the Nantucket Bluefish Tournament in August and the Martha's Vineyard Striper and Bluefish Tournament in September and October.

The charter and partyboat fishery has long been one of the major components of the Massachusetts salt water sportfishery. Operating out of ports on Cape Cod and Martha's Vineyard, 42 charter vessels and 10 head boats traverse the Sound, and concentrate on the many bars and shoal areas that provide prime fishing opportunities.

C. RECREATIONAL BOATING

Nantucket Sound is a nationally prominent recreational boating area. The high water quality, the protected water body, the numerous harbors and boating facilities and the attractiveness of the shore areas attract boats from many placed on the East Coast.

Approximately 11,600 recreational craft are based at over 30 harbors located in Nantucket Sound. These harbors contain 47 marinas, 44 boat yards, 18 yacht clubs, 11 boat rentals, 7 public docks, 30 public launching ramps, 13 mooring areas and 13 jetties or fishing piers. Hyannis and Edgartown host major sailing regattas each summer.

D. GENERAL RECREATIONAL ACTIVITIES

The Nantucket Sound area including the coastal regions of Cape Cod and the islands is a premier regional and national marine recreational resource. The Nantucket Sound area is unique in its distinctive combination of cultural and natural resources. Cape Cod and the islands have to a large degree retained their architectural character with attractive small villages in a relatively unspoiled natural setting. The coastal shores consist largely of sea cliffs, sand dunes, sandy beaches, tidal marshes and shallow estuaries. The waters of Nantucket Sound and the fresh water streams that flow into the Sound are generally of excellent quality.

The Nantucket Sound area is slightly more than two hours away from metropolitan Boston and within one day's drive of one-third of the nation's population. This accessibility, coupled with the aesthetic, natural and recreational attractiveness of the area has resulted in the development of a thriving and expanding tourist industry.

In 1978, there were approximately 13,224,000 visitor days in Barnstable (all of Cape Cod), Dukes (Martha's Vineyard and the Elizabeth Islands) and Nantucket counties. Martha's Vineyard is the largest island in New England. The island's coastal features including clean warm waters, good beaches, salt ponds, attractive ports and sheltered harbors support the many marine dependent recreational activities that form one of the mainstays of the island's economy. Martha's Vineyard has been an active summer resort for over 100 years. The Steamship Authority which provides the primary access to the islands carried in 1979 96,604 automobiles and 545,626 passenger across Nantucket Sound to Martha's Vineyard from ports on Cape Cod.

Nantucket, the outermost county of Massachusetts, is 50 square miles in area and lies 30 miles to sea. The island was the center of the nineteenth century whaling industry. When this industry collapsed, the island entered a long period of economic decline. The island's remoteness and lack of economic growth allowed

Nantucket to retain its traditions and architectural heritage. Over 500,000 tourists each year visit this "living museum" of nineteenth century maritime America. As is the case with Martha's Vineyard, most of the visitors to Nantucket reach the island by crossing the nominated area by boat. An integral part of the attractiveness of these islands to the visitors is the ferry voyage across the waters of Nantucket Sound.

In 1978, Barnstable County exhibited the greatest total expenditures by visitors and the greatest number of visitor days of all the counties of the Commonwealth. A large percentage of these visitor days occurred in the areas facing Nantucket Sound, as a majority of tourist and marine-related recreational facilities on Cape Cod are located along its southern shoreline. Informal surveys by the Cape Cod Chamber of Commerce, the Martha's Vineyard Commission and the Nantucket Economic Development and Planning Commission indicate that between 50 and 60% of the visitors to the area are from out-of-state.

The following tables list the basic tourist statistics for 1978 and a comparison of visitor days and expenditures for 1976,77 and 78.

COUNTY & STATE TOURIST STATISTICS: 1978

County	Total Visitor Days	Total Expenditure	Employment due to Travelers	Payroll paid by Travelers
Barnstable	11,673,714	$320,307,000	12,598	$ 65,127,000
Dukes	888,000	23,588,000	868	4,771,000
Nantucket	662,868	19,118,000	699	3,897,000
Total	13,224,582	$363,013,000	14,165	$ 73,795,000
State	42,641,749	1,241,069,000	51,063	263,627,000
% of State	31%	29%	28%	28%

VISITOR DAYS AND TOTAL EXPENDITURES: 1976, 1977, 1978

County	1976	1977	1978	1976	1977	1978
Barnstable	11,316,637	12,225,203	11,073,714	270,753,000	300,941,000	320,307,000
Dukes	717,744	920,132	888.000	16,169,000	21,410,000	23,588,000
Nantucket	596,038	687,407	662,868	14,470,000	17,616,000	19,118,000
TOTAL	12,630,419	13,833,742	12,624,582	301,392,000	322,351,000	363,013,000

(Counover & Kindahl "Travel and Tourism in Massachusetts, 1978, 1979)

The primary activity of tourists in the Nantucket Sound area is marine related recreation. The beach and the water are prime attractions and access to the beach and the quality of the beach and adjoining waters as a critical factor in the decision of people to spend their vacation in this particular area.

There are 52 public beaches (town and state) with a total shore length of 16.5 miles and 13 private beaches with 19 miles of the shoreline facing the waters of Nantucket Sound. The Commonwealth is in the final stages of purchasing an additional beach frontage in the Town of Mashpee.

V. IMPACTS OF PRESENT AND POTENTIAL USES ON NANTUCKET SOUND AND ITS UNIQUE RESOURCES

A. Introduction

The focus and intent of this nomination is to maintain the integrity of Nantucket Sound area for its marine productivity and its unique aesthetic, historic and recreational value. This can best occur if there is a management regime for the centralwaters that complements the existing ocean sanctuary regime for Massachusetts coastal waters Potential uses of the nominated area will be discussed in terms of their impact on the ecological, historic, recreational and aesthetic values of the area.

B. Fishing Activity

Commercial and recreational fishing are important uses of the Sound and of increasingly important economic value to the developing Massachusetts marine fishing industry and the local economies of Cape Cod, Martha's Vineyard and Nantucket. Commercial fishing of traditional and non-traditional species in near-shore waters is becoming more and more important as the demand for fish products increase along with the ever escalating costs of steaming time of the fishing fleet to and from George's Bank.

The Massachusetts Division of Marine Fisheries provides the existing management of fisheries in Nantucket Sound and conducts stock assessment studies and other fishery related research in the area. This nomination letter, proposes that the Division of Marine Fisheries (EOEA) and the New England Fisheries Management Council manage the fisheries of the nominated area within the existing fishery management framework. A unified management structure for the commercial fisheries in Nantucket Sound is one of the purposes of this sanctuary nomination and would not adversely impact the fisheries or the other distinctive features of Nantucket Sound.

C. Oil and Gas Development and Transmission

Exploration and development of oil and gas from the sea bed of Nantucket Sound or the transmission of oil and gas through the Sound would pose a serious threat to the ecological, recreational, historic and aesthetic features of the area.

1. Oil and Gas Exploration, and Development

The potential for oil and gas development and production in Nantucket Sound is low. The seismic profiles collected through the USGS/DPW co-operative program reveal that the subsurface geology does not support the formation of oil or gas deposits.

2. Oil and Gas Pipelines

The exploration for oil and gas reserves of Georges Bank will be actively under way in 1981. The establishment of pipeline routes from George's Bank to accessible port facilities on the southern shoreline of Cape Cod, nearby Buzzards Bay and Mt. Hope Bay present strong possibilities for the location of pipelines through Nantucket Sound. However, the geological characteristics of the sea bed of the nominated area creates serious construction problems for potential pipelines. Nantucket Sound contains mobile bottom bedforms which effect the structural stability of pipelines in several ways. First, if the pipeline is not buried to a depth well below the effective reach of the bedform features and into the more stable subbottom, the pipeline could be left suspended high above the Sound floor as the bedforms migrate. Secondly, the great weight that a large, migrating bedform would exert as it passed over a pipeline increases the likelihood of collapsing or shearing the line.

The construction of a pipeline in the nominated area would require a tremendous excavation of material on the seabed on the Sound. This would have a serious adverse impact on the finfish and shellfish spawning areas, permanently alter feeding habitats of the large waterfowl populations of the Nantucket Sound area and disrupt the habitats of marine mammals and sea turtles in the area.

3. Oil and Gas Transporation

The shortest and most direct route from Georges Bank to the mainland is through Nantucket Sound. If the decision was made to transport the oil and gas production from George Bank by barge or tanker, the producers might well seek to route the traffic through Nantucket Sound. The petroleum would be then transferred at facilities in the port areas or possibly via floating transfer docks located in the Sound. This would only increase dramatically the danger of contamination from oil spills, increase collision danger with the many recreational boaters and impair the aesthetic and visual experience that hundreds of thousands of tourists annually obtain from the area. The numerous shoals and mobile bedform characteristics of much of the nominated area makes for hazardous navigation and increases the risk of spillage.

Increase traffic could also have adverse impacts on the resident biota. The increase flow of traffic could disturb a wary grey seal population perhaps to the point of driving it from its Nantucket Sound habitat. Transportation-related facilities and structures would significantly alter the ecosystem of the Sound and perhaps make it undesirable for certain species.

4. Impacts of Oil Pollution on the Resources of Nantucket Sound

One of the major threats to the continued wellbeing of the resources of the nominated area as well as Nantucket sound as a whole would be chronic oil seepage from pipeline(s), the rupture of a pipeline or the collision or sinking or an oil barge resulting in major oil spill.

The impact of oil on the marine environment has been thoroughly documented and discussed in detail in numerous journals and reports. It would suffice to limit discussion in this nomination letter to a summary of the specific impact of oil pollution on the resources of Nantucket Sound.

Responses of the marine biota to petroleum pollution range from the immediately lethal to long-term sublethal effects including interference succeptibility to predation. Immediately lethal effects are caused by high levels of exposure to petroleum, particularly petroleum with a high aromatic content. It is accutely toxic in this state to virtually all marine organisms (birds, mammals, fish, plankton, and microbes) primarily through smothering and clogging action. After the petroleum has had time to weather, it has only minor impact on marine macroorganisms, with a few notable exceptions.

The consequences of the current patterns in Nantucket Sound makes the impact of any major spill in the Sound potentially castastrophic as the petroleym hydrocarbons would be quickly dispersed over the entire water body. The impact of an oil spill would be especially severe in the biological sensitive areas of the nomination area and the adjacent shorelines with their economically important beaches, shellfish beds and productive estuarine habitats.

i. Marine and Shore Bird Populations

The various bird populations in the Nantucket Sound area would register an immediate and drastic impact upon exposure to petroleum products. They would be vulnerable to oil fouling and poisoning from ingestion of fish that have been contaminated with petroleum compounds. Fouling of the shoal areas in the Sound would be particularly devasting to the many bird species that use the area as a feeding ground.

ii. Marine Mammals and Reptiles

Nantucket Sound contains the only known habitat in the United States of the North Atlantic grey seal. This species is extremely vulnerable to environmental disruptions because of their highly restricted range and high level of sensitivity to petroleum products. A single major oil spill could cause significant reduction in the small population and force the grey seal to abandon its Nantucket Sound habitat. For example, the grey seal herd normally produces from one to three pups a year. In 1978, following the Argo Merchant spill, none were seen.

Sea turtles are also highly vulnerable to petroleum contamination by ingesting floating objects such as tar balls.

iii. Wetlands

The highly productive and fragile coastal wetlands system on the Cape Cod's south shore and the islands would be particularly vulnerable to an oil spill occurring in the central section of the Sound. The unrestricted openings of the estuaries, the close proximity to the point of any spillage in the Sound and the strong circular tidal action would move slicks and surface contamination directly into the wetlands. Restricted flushing in the confined embayments contain and concentrate oil contaminants and toxic chemicals thus magnifying their impact on the marine organisms that come there to feed, breed and spawn. The wetland peat substrate is highly absorptive. Materials like petroleum are readily retained and slowly released into an estuarine environment up to ten years. These chronic low level releases of petroleum can produce continued contamination of the sensitive estuarine resources. The 2500 acres of salt marshes in these estuaries are important spawning and nursery areas for many species of finfish found in the nomination area. They also support many local species of birds and provide migratory habitats for the many bird populations using the Atlantic Flyway.

iv. Shellfishing

The main adverse impact of an oil spill on shellfishing is the tainting of meat due to the accumulation of oil residue in the shellfish. This could lead to the closing of the area to shellfish harvesting for a number of years due to oil contamination of the shellfish beds. The closing of shellfish beds could lead to the overutilization of remaining areas thus diminishing breeding stocks.

v. Sport Fisheries

The short term impact of an oil spill on sport fishing would result in the loss of fishing opportunities caused primarily by (1) the physical presence of an oil slick and the dispersion of the fish population, (2) fouling of fishing gear and (3) the incorporation of oil into the sediments which may lead to a reduction and/or contamination of the benthic organisms. If a spill were to impact one of the anadromous fish runs during a run, the fishing for alewives would be interrupted for the duration of the spill. Since most runs are relatively short, a spill would probably preclude any fishing for that year. If a spill were to occur during the time when young fish are migrating to sea, they could suffer high mortality rates.

vi. Recreation

If an oil spill were to impact the recreation beaches in the Sound during or just prior to the tourist season, there could be an adverse impact for the remainder of the season. Even if clean-up efforts were completed immediately, publicity on the spill would detract from the overall reputation of the area.

A 1979 report prepared for the federal Office of Coastal Zone Management applied the economic hedonic pricing model to estimate the cost associated with polluting beaches in the Cape Cod and Martha's Vineyard area of Massachusetts. The basic assumption of this model is that a tourist renting a coastal accomodation is renting a package of characteristics including the accomodation itself, nearby tourist facilities and the surrounding environment. The "package" for virtually all tourist accomodations on Cape Cod and Martha's Vineyard includes the proximity, the quality and access to beaches. If the quality of a beach is reduced due to pollution, the tourist willingness to pay will be reduced along with a decrease in the area's rental income. This study found that if all the beaches of Buzzard's Bay were polluted to the degree of being unusable for the duration of the tourist season, the loss in rents alone would be about $1,100,000.

D. Sand and Gravel Mining

Ocean mining of sand and gravel is a major industry in many parts of world and improvements are continuously being made in extraction technology. Because of its proximity to shore, the existence of large deposits of sand and gravel relatively near the surface and sheltered waters for mining operations, Nantucket Sound is a potential site for sand and gravel mining.

1. Large scale removal of sand deposits would change bottom topography, and therefore, the currents and substrate characteristics over time. This would not only impact the immediate area of mining, but could also create an artificial sediment sink which would draw adjacent sediment into the void at an unnaturally high rate. The main impact would be the alteration and disruption of benthic habitats during excavation. Substrate removal is a serious threat to benthic communities, since the species compositon of a community is primarily determined by substrate characteristics.

2. Excavation also resuspends an enormous volume of sediment in the water column, increasing turbidity levels and causing silt-related suffocation that could devastate sensitive spawning and nursery areas. Light penetration is reduced, reducing the rate of primary production, diminishing the standing crop or biomass, and thus the amount of food available to primary (and ultimatley secondary, etc) consumers. Smaller particles of suspended matter can remain in suspension for long periods of time and over great distances (over 0.5 miles), extending negative impacts beyond the local area.

3. Excavation of large quantities of material from Nantucket Sound would permanently disrupt the feeding grounds for the large bird populations utilizing the many refuges of the Nantucket Sound Area.

4. Excavation could permanently adversely impact sites of historic value in Nantucket Sound. The many shipwrecks located in the proposed sanctuary area could easily be permanently destroyed by sand and gravel mining opreations.

5. Negative aesthetic impacts would result from the placement of dredging and mining equipment in Nantucket Sound. A very strong, negative visual impact would be felt in areas of Nantucket Sound from which the equipment was visible. Several studies have documented that individuals participating in recreational activities place a high priority on the visual quality of an area in the selection process to decide where to spend their recreational time.

6. The placement of sand and gravel mining equipment in stationary locations in Nantucket Sound increases the danger of collision in a heavily travelled area which is susceptible to sudden fogs.

E. Ocean Dumping

The disposal of dredge spoil materials has both acute and chronic biological effects. Many benthic and free-swimming organisms are buried or suffocated by dumped spoil. Contaminated dredge spoil disposal would cause significant disruption in the benthic habitats.

The many harbors bordering Nantucket Sound and in other coastal areas of southeastern Massachusetts will require maintenance dredging during this decade. While much of the material to be dredged from Nantucket Sound harbors is clean fill, the dredge spoil from the inner harbors (Falmouth, Hyannis and Nantucket) and the harbors in southeastern Massachusetts such as Fall River and New Bedford contain concentrations of heavy metals.

A 1980 bedform morphology study of Nantucket Sound prepared for the United States Geological Survey indicates that a majority of the bottom of the proposed marine sanctuary area consists of mobile bedforms migrating in response to strong tidal currents. Material disposed of in this environment would be dispersed throughout the Sound quite rapidly even if it had been caped with an overlay of clean sediment. This report, however, did identify two potential areas in Nantucket Sound that may be suitable in terms of hydrographic considerations for ocean disposal of dredge-spoil material. There areas include part of the northern and southeastern sections of the proposed marine sanctuary site. This identification was conditioned with the need for further study of the local bottom water circulation and sediment transport conditions.

F. Sewage Outfall and Sludge Disposal

The location of a sewage outfall within the nominated area is quite remote because of the prohibitions of the Cape and Islands State Ocean Sanctuary and the tremendous cost of laying three miles of outfall pipe.

However, the use of the proposed sanctuary waters as a site for wastewater sludge disposal is entirely feasible. The discharge of wastewater sludge into the Sound would negatively impact the ecosystem by altering the physio-chemical balance which now supports the diversity of species in the area. Benthic communities would be smothered with each sludge dumping, filter feeding macroorganisms would be exposed to bacterial and viral contamination and bottom feeding fishes would likewise be contaminated. The creation of sludge blankets and areas of low dissolved oxygen would adversely affect organisms in the dumping area. Sludge disposal would also increase the turbidity in the water column, decrease visibility and light penetration.

G. Underwater Archaelogical Excavation

The many shipwrecks that lie within the nominated area are important for their value in interpreting American maritime history. Unregulated excavation and salvaging of these wrecks and their associated artifacts could easily result in the permanent loss of these historically valuable resources. It is necessary that all excavating and salvaging activities be carefully reviewed and regulated through a permitting process that would be pursuant of regulations adopted for the proposed Nantucket Sound Marine Sanctuary.

VI. PROBABLE EFFECTS OF SANCTUARY DESIGNATION AND REGULATION ON CURRENT AND FUTURE USES

A. Fishing Activities

Existing commercial and recreational fisheries management activities within the nominated area are being accomplished by the Massachusetts Division of Marine Fisheries (EOEA). Since the purposes of this marine sanctuary designation are intended to provide for a unified resource management regime for the entire sound, it is the intent of this nomination that the Division of Marine Fisheries (EOEA) and the New England Fishery Management Council manage the fisheries of Nantucket Sound within the existing fish management framework.

B. Other Activities

All activity other than fishing would be regulated by standards adopted in the proposed Nantucket Sound Marine Sanctuary regulations. In order to establish uniform standards for all the waters of Nantucket Sound, this nomination proposes that the scope and substance of the standards for the proposed Nantucket Sound Marine Sanctuary conform with the standards contained in the Massachusetts Sanctuaries Act as applied in the Cape and islands Ocean Sanctuary.

All proposed activities and consistency determinations would be reviewed in light of the purposes of the sanctuary to protect and enhance the ecological, recreational, historic and aesthetic resources of Nantucket Sound.

1. Oil and Gas Exploration, Development and Transmission

It is proposed that the drilling or removal of gases or oils and the building of any structure on the seabed or under the suboil including without limitation any structure for the extraction or transportationo of resources such as gases or oils, would be prohibited under the marine sanctuary regulations.

2. Sand and Gravel Extraction

Mineral extractions within the marine sanctuary would be severely limited under the proposed regulations. The extraction of any sand or gravel from the seabed for subsoil would be prohibited unless such sand and gravel is to be used for shore protection or beach restoration projects.

3. Ocean Dumping

The dumping or discharge of commercial or industrial wastes, the disposal of debris or contaminated dredge spoil material and the dumping of wastewater treatment sludge would be prohibited within the marine sanctuary. The incineration of solid waste material or refuse on or in vessels moored or afloat would also be prohibited within the boundaries of the sanctuary.

4. Ocean Outfalls

Municipal wastewater treatment discharge outfalls would be prohibited within the marine sanctuary.

5. Underwater Archeological Excavation

It is proposed that all underwater archeological salvaging within the marine sanctuary by subject to careful review and permitting.

VII. SANCTUARY MANAGEMENT

A. Introduction

Nantucket Sound serves as a habitat and species area for a wide variety of fish; a habitat area for a number of endangered or threatened mammals and reptiles; a key feeding area for diverse and extensive bird populations; supports a growing commercial and recreational fishery; houses a number of historical shipwrecks and is an integral part of one of the premier marine recreational and boating areas of the East Coast. In addition to the ongoing fishing activities in Nantucket Sound, possible future activities include oil and gas pipelines, expansion of existing transportation uses to include the barging of oil and gas deposits from George's Bank, installation of floating oil and gas transfer docks, sand and gravel mining, disposal of dredged spoil material, dumping of waste water treatment sludge and archaeological excavation.

All of these current and potential activities impact and will impact the many distinctive ecological, recreational, historic and aesthetic resources of Nantucket Sound. The resources that are found in the Massachusetts coastal waters of Nantucket Sound are adequately protected through the provisions of the Massachusetts Sanctuaries Act, the fish management programs of the Massachusetts Division of the Marine Fisheries and other applicable state environmental laws. Without designation of the federal waters of Nantucket Sound as a marine sanctuary, the core of this important waterbody would not be adequately protected from possible future activities and there would be no cohesive, integrated management system for the area as a whole. Designation of Nantucket Sound as a marine sanctuary under the management of the Massachusetts Executive Office of Environmental Affairs would provide a needed comprehensive management system for the entire Nantucket Sound area.

B. Existing Management of Massachusetts Coastal Waters in Nantucket Sound

The Massachusetts coastal waters come under the purview of the Massachusetts Ocean Sanctuaries Act, the Massachusetts Coastal Zone Management Plan, the Massachusetts Environmental Policy Act, the Massachusetts Wetlands Protection Act, the Massachusetts Coastal Wetlands Restrictions Act, the Massachusetts Clean Water Act, the fish management policies of the Massachusetts Division of Marine Fisheries and the Massachusetts Underwater Archelogy Act.

1. The Ocean Sanctuaries Act (Mass. General Laws, chapter 132A, sections 13-16 and 18)

Established sanctuaries along the coastline of Massachusetts to protect these water bodies from any exploitation, development or activity that would seriously alter or otherwise endanger the ecology or the appearance of the ocean, the seabed for subsoil thereof, or the Cape Cod National Seashore.

The Cape and Islands Ocean Sanctuary was established in 1971 and includes all the Massachusetts Coastal waters of Nantucket Sound. Among the activities that are prohibited in the Cape and Islands Ocean Sanctuary are: the building of any structure on the seabed or under the subsoil; the construction or operation of offshore or floating electric generating stations; the removal of any minerals, such as sand or gravel,; the drilling for gas or oil; the dumping or discharge of any commercial or industrial wastes; municipal wastewater treatment discharge; commercial advertisement by any means, including, but not limited to structures or vessels or boats of any size and the incineration of solid waste material or refuse on, or in, any vessel or boat of any size within the boundaries of the sanctuary.

The harvesting and propagation of all finfish and shellfish is permitted provided that the Massachusetts Department of Environmental Management and the Massachusetts Division of Marine Fisheries are satisfied that such activities will be carried out in accordance with sound conservation practices.

2. Massachusetts Coastal Zone Management Program

The Massachusetts Coastal Zone Management Program was approved by the Department of Commerce in April, 1978 and focuses on protecting, developing and enhancing the important resources of the Massachusetts coastal zone. The Massachusetts coastal zone extends from the seaward limit of the state's territorial sea and landward to 100 feet inland of the first major road, rail line or 100 feet inland of the 100 year flood plain along tidal rivers or Anadromous/Catadromous fish runs. The Coastal Zone includes all of Cape Cod, Martha's Vineyard and Nantucket. The Massachusetts Coastal Zone Management Office reviews for consistency with the approved plan all proposed federal permits, licenses, funding actions in or affecting the coastal zone to include off-shore oil and gas exploration and development plans and activities.

3. The Massachusetts Environmental Policy Act (Mass. General Laws chapter 30, section 51 and 62)

Establishes an environmental review process for all actions requiring state permits and those to be conducted by state agencies. Activities which are regulated by this Act include the construction of structures in a waterway or any onshore facility with potential impacts on land and water.

4. Massachusetts Wetlands Protection Act (Mass. General Laws chapter 131, section 40)

Authorizes local Conservation Commissions to review and condition any proposal to remove, fill, dredge or otherwise alter any freshwater or coastal wetland, beaches, dunes, flats, marshes, meadows or swamps bordering on the ocean or on any estuary, creek, river, stream, pond, or lake; any land under these waters; or lands subject to tidal actions, coastal storm flowage or flooding. At the state level, the Department of Environmental Quality Engineering may entertain appeals of locally issued Orders of Conditions and issue and enforce superceding orders.

5. <u>Massachusetts Coastal Wetlands Act (Mass. General Laws, chapter 130, section 105)</u>

Authorizes the Commissioner of Environmental Management to adopt orders restricting or prohibiting dredging, filling, removing or otherwise altering or polluting wetlands. These wetlands include banks, marshes, swamps, meadows, flats or other low lands subject to tidal action or coastal storm flowage and contiguous lands such as coastal beaches, barrier beaches, coastal dunes, banks and rocky intertidal shores.

6. <u>Massachusetts Rules for the Prevention and Control of Oil Pollution in the Waters of the Commonwealth</u>

The Division of Water Pollution Control has been charged by the Commonwealth with the responsibility for preventing and controlling the discharge, spillage, seepage or filtration of oil into the waters of Massachusetts and reviewing and permitting all municipal water supply and water treatment facilities.

7. <u>Marine Fisheries (Mass. General Laws, chapter 130, section 19 et al.)</u>

The Division of Marine Fisheries, with the approval of the state Marine Fisheries Advisory Commission, manages the fisheries in coastal waters to include establishing the manner of taking fish, legal size limits, seasons, numbers and quantities of fish which may be taken and the opening and closing of areas. The Division is also charged with aiding the promotion and development of the commercial fishing industry and conducting fisheries management research in Massachusetts coastal waters.

8. Massachusetts Underwater Archaeology Act (Mass. General Laws, chapter 6, sections 179 and 180)

Establishes a Board of Underwater Archaeological Resources to protect and preserve historical, scientific and archaeological information about underwater archaeological resources located within the inland and coastal waters of the Commonwealth. The Board reviews and issues permits for any removal or salvage of underwater resources that have historical and educational value, oversees salvage and recovery operations and maintains an inventory of underwater archaeological resources. This Act further declares that title to all underwater archaeological resources to be in the Commonwealth of Massachusetts.

C. Existing Management of the Proposed Nantucket Sound Marine Sanctuary Area

The area being proposed as Nantucket Sound Marine Sanctuary comes under the jurisdiction of different federal programs. These programs do not provide the extent of resource protection currently existing for the surrounding Massachusetts coastal waters through the provisions of the Massachusetts Ocean Sanctuaries Act, other Massachusetts environmental laws and the fish management programs of the Division of Marine Fisheries.

Designation of a Nantucket Sound Marine Sanctuary would clearly establish protection, conservation and enhancement of the ecological, recreational, historic and aesthetic features as the primary management objectives of the federal waters of Nantucket Sound. Such a designation would also compliment the surrounding Cape and Islands Ocean Sanctuary and would provide a unified resource management regime for all the waters of Nantucket Sound.

The following is a summary of the federal resource management programs that presently effect the proposed marine sanctuary area.

1. The Ocean Dumping Section of the Marine Protection, Research and Act Citation, regulates the dumping of dredged material, solid waste, sewage sludge, chemicals, rock, sand and other wastes from any vessel originating in the U.S. The U.S. Environmental Protection Agency issues dumping permits only if it can be shown that the waste will not "unreasonably degrade or endanger...the marine environment, (or) ecological systems..." While this law will prevent dumping of certain substances, it neither totally prohibits the dumping or discharge of commercial or industrial wastes, contaminated dredge spoil material, or municipal wastewater treatment sludge, or prevents oil spills from pipeline seepage or rupture. The law controls only that petroleum which is on board a vessel for the express purpose of dumping at sea.

2. The Massachusetts Coastal Zone Management Plan (MCMZP) incorporates the state's Ocean Sanctuaries Act and establishes the provisions of this Act as one of the main regulatory tools to protect the quality of the coastal water bodies. The designation of the central portion of Nantucket Sound as federal waters and its subsequent removal from the jurisdiction of the Cape and Islands Ocean Sanctuary reduces the role of the Massachusetts Coastal Zone Management (Plan in the Commonwealth's efforts) to conserve and enhance the coastal environment of Nantucket Sound. Although the Massachusetts Coastal Zone Management Office would continue to review for consistency with the MCZMP those development activities being proposed in federal waters of the Sound that would affect land and water uses within the coastal zone, its review would be limited in so far as the prohibitions of the Massachusetts Ocean Sanctuaries Act would no longer apply to these waters. However, the proposed designation of the Massachusetts EOEA as the onsite manager of the Nantucket Sound Marine Sanctuary is intended to help ensure that such environmental protection remains applicable to both state and federal waters of the Sound.

3. <u>The Outer Continental Shelf Lands Act</u> wouldbe the primary federal law governing oil and gas development and pipeline construction in the federal waters of Nantucket Sound. Newly enacted amendments to the OCSLA add certain environmental safeguards and provide for the compensation of economic losses due to oil spills. The provisions of the amended Outer Continental Shelf Lands Act, might protect the distinctive resources of Nantucket Sound from some of the hazards of any potential oil and gas transmission activities. However, since the protective provisions in the OCSLA are designed to lessen potential conflicts on a nation-wide basis, they fail to recognize the unique distinctive resoursces of Nantucket Sound and to provide the special level of safeguards required in this area. Therefore, if oil and gas transmission activities in Nantucket Sound were governed primarily by the OCSLA, the primary emphasis of the managing agency, the Department of the Interior, would be the transshipment of oil and gas reserves to the mainland.

4. <u>The Port and Tanker Safety Act of 1978</u> authorizes the Department of the Treasury and the Coast Guard to regulate shipping and navigation for several purposes, including protection of the marine environment. The Act imposes specific requirements on oil-carrying vessels, such as minimum standards for tanker design, construction, equipment and manning. It also authorizes, but does not direct, the Secretary to regulate vessel operations in certain areas. While this Act goes a long way towards preventing disastrous oil spills from barge and tanker collisions, it touches only one aspect of the potential danger to the resources of the Sound from oil spillage.

5. <u>Fisheries Management</u>

Fisheries within the nominated marine sanctuary area are not currently regulated under any specific federal or state regulations. The Commonwealth does license Massachusetts boats fishing in the nominated area and specific research activities that have occurred in this area have been conducted by the Massachusetts Division of Marine Fisheries. Since 1964, the Massachusetts Division of Marine Fisheries has conducted fishery resource assessments for all the waters of Nantucket Sound. These fishery management studies were partially funded in the earlier years with funds made available by the Commercial Fisheries Research and Development Act (P.L.88-309) and recently with grants from the National Marine Fisheries Service. The current surveys are part of a Coastwide Fishery Resource Assessement being conducted by NMFS. During this period, all or most of the fishery management research in Nantucket Sound has been conducted by the Massachusetts Division of Marine Fisheries.

If the previously mentioned settlement agreement is consumated, the Fishery Conservation and Management Act would come into play for the federal waters of the Sound. The Fishery Conservation and Management Act of 1976, 16 U.S.C. (1801, et seq.), as amended (FCMA) extends the authority of the United States over marine fisheries to a "fishery conservation zone" (FCZ) which encompassesan area beginning at the seaward boundard of each of the coastal states and extending to a line 200 nautical miles from the base line (or 197 nautical miles from the states' seaward boundaries). 16 U.S.C. (1811). The FCMA created eight Regional Fishery Management Councils authorized to develop fishery management plans (FMPs) for fisheries within their geographic areas. 16 U.S.C. (1852). FMPs developed and approved by these councils are submitted to the Secretary of Commerce for approval and implementation through federal rulemaking. 16 U.S.C. (1853) (c).

D. PROPOSED MANAGEMENT PLAN

1. Summary

i. NOAA shall have the responsibility for the overall management of the Sanctuary pursuant to the delegation of authority from the Secretary of the U.S. Department of Commerce to the Administrator of NOAA issued on March 19, 1974.

ii. It is proposed that NOAA designate the Executive Office of Environmental Affairs (EOEA) to serve as the on-site manager of the Sanctuary. EOEA will carry out its responsibilities within the framework of the rules and regulations to be promulgated by NOAA which pertain to the Sanctuary.

iii. The U.S. Coast Guard and the Division of Law Enforcement (EOEA) shall have the responsibility for the surveillance and enforcement of the regulations.

iv. An Advisory Board shall be established to assist NOAA and EOEA in the management of the sanctuary.

2. NOAA's Responsibilities

i. NOAA is responsibile for the overall management of the marine sanctuary.

ii. NOAA reviews and approves:

a. management plans for the marine sanctuary prepared by Executive Office of Environmental Affairs; and

b. research programs designed by Executive Office of Environmental Affairs

iii NOAA issues final consistency certificates that proposed activities are in conformance with the purposes for which the sanctuary was established.

iv. NOAA oversees environmental monitoring and enforcement of regulations.

v. NOAA provides financial support to Executive Office of Environmental Affairs for it to carry out its managerial functions.

3. EOEA's Responsibilities

i. EOEA is responsibile for the day to day management of the sanctuary.

ii. EOEA prepares management plans & designs research programs,

iii. EOEA implements the management plans, research and public information programs.

iv. EOEA reviews any applications for permits, licenses or other authorizations as to the proposed activity's consistency with the purposes for which the sanctuary was established and the regulations promulgated for the sanctuary. After completing the evaluation, EOEA submits a recommendation to NOAA as to whether or not NOAA should certify the proposed activity.

v. EOEA, in cooperation with the U.S. Coast Guard is responsible for the enforcement of the sanctuary regulations.

4. Advisory Board

i. An advisory board shall be established to assist NOAA and EOEA in managing the sanctuary.

ii. The advisory board will have the following duties:

a. advise NOAA and EOEA on the setting of priorities for NOAA funding of sanctuary programs;

b. review the management of the sanctuary on an on-going basis and recommend to EOEA and NOAA changes in the sanctuary regulations and/or management procedures; and

c. at the request of EOEA, review and comment on permit and certification applications.

5. Consistency Review

i. Section 302(f) of the Marine Sanctuaries Act states that: "After a marine sanctuary is designated...no permit, license or other authorization issued pursuant to any other authority shall be valid unless the Secretary of Commerce shall certify that the permitted activity is consistent with the purposes of this title and can be carried out within the regulations promulgated under this section."

ii. All federal and state agencies are required to notify NOAA of any pending application for a permit, license or other authorization to conduct an activity within the boundaries of the sanctuary.

iii. Upon receipt of the notification, NOAA will send a copy of the notification to EOEA. EOEA will evaluate the notification documents and submit a recommendation to NOAA within 30 days of the receipt of the notification.

iv. Either NOAA or EOEA may request additional information as it deems necessary from the permit, license or other authorization applicant.

v. EOEA may elect to seek the advice of the Advisory Board as to whether or not NOAA should certify that the proposed activity on the part of the applicant is in conformance with the purposes for which the sanctuary was established.

6. Permits for Scientific Research

i. Upon receipt of a permit application, NOAA will send a copy of the application to EOEA. EOEA, in conjunction with the Massachusetts Board of Underwater Archeological Resources will review the merits of the application and will submit a recommendation to NOAA within 30 days of receipt of the application.

ii. The permit applicant shall be notified within 60 days from date of receipt by NOAA as to whether or not the permit application has been approved. Either NOAA or EOEA may request additional information as it deems necessary from the permit applicant consistent with the treaty obligations of the United States.

iii. Upon receipt of the application, EOEA may elect to seek the advise and recommendations of the Sanctuary Advisory Board.

7. Enforcement

i. Enforcement of the Sanctuary regulations shall be accomplished through a joint cooperative effort between the Massachusetts Division of Law Enforcement and the U.S. Coast Guard. The U.S. Coast Guard, pursuant to 14 U.S.C. Section 89, shall have responsibility for the citation of all violations of the Sanctuary regulations.

ii. The Attorney General of the United States shall, on the written request of NOAA, or EOEA, or on his own initiative, commence the appropriate action in the United States District Court to restrain violations of the sanctuary regulation and to collect the unpaid penalties assessed for violations of the such regulations.

E. RECOMMENDED RESEARCH AREAS

During the course of preparing the Nomination Letter, the following have been identified as some of the areas for future research:

1) Cultural Resources

Nantucket Sound contains a large number of shipwrecks and their associated artifacts. An historic assessment needs to be completed to determine the exact location of the wrecks, their condition and historic value in order to provide a rational foundation for managing these resources.

2) Fisheries Assessment

The Massachusetts Division of Marine Fisheries has been conducting a semi-annual bottom trawl survey in Nantucket Sound since 1978. The objectives of this fishery resource assessment include:

i. estimate relative abundance of groundfish and certain shellfish species in terms of weight and numbers.

ii. determine periodic trends in finfish abundance, population structures and species composition.

iii. collect information on age and growth, maturity, food habits, mortality and recruitment.

iv. describe fish distribution in relation to temperature, salinity, and depth.

In order to allow for a more rational conservation and management of the fisheries, the current fisheries assessment efforts should be expanded to provide a more in-depth analysis of species breeding habitats, migration, growth, mortality, recruitment, distribution and abundance. Also, an evaluation needs to be conducted of the potential impacts of the marine sanctuary of the new technological innovations for use in the fishing industry.

3) Marine Birds, Mammals and Reptile Research

The proposed marine sanctuary is an habitat for many species of marine birds marine mammals and reptiles. Several of these species have rare, endangered or threatened status such as the grey seal and the green turtle. To ensure the protection and the enhancement of these species, additional research is needed on their habitats, migration and feeding patterns, breeding and nursery habits, distribution and abundance.

4. Geological Features

The relatively flat seabed and shallow waters of the Sound bounded by Cape Cod and the Islands make this semi-enclosed sea a distinctive area for marine geologic and physical oceanographic research.

Pre-glacial geology, seafloor topography and tidal currents have been studied by various private and public agencies. Additional studies are needed to:

i. determine the developmental characteristics and migration pattern of the Sound's bedform features. Specifically this should include the determination of sediment source, formative mechanics and movement patterns through the collection of time series data.

ii. reconstruct the geological history of the Sound in relation to Cape Cod.

iii. detail map the surficial sediments and tidal currents.

iv. study the physical, chemical and biological impacts of the disposal of clean dredged material in Nantucket Sound.

5. Recreational Activities

Little research has been conducted on the recreational opportunities and potential for Nantucket Sound as a unified geographic area. Some of the research that could be conducted include:

i. research and map existing recreational facilities and public access areas enabling visitors to reach the proposed sanctuary.

ii. develope a recreational guide to Nantucket Sound including a detailed description of the areas unique natural, cultural, historic and recreational resources.

VIII. AVAILABLE DATA ON THE RESOURCES OF NANTUCKET SOUND

A. Woods Hole Oceanographic Institution (WHOI) is a research institution whose physical and political scientists are very knowledgeable of the natural and man-made resources of the Nantucket Sound Area.

B. The Massachusetts Division of Marine Fisheries (EOEA). The Division of Marine Fisheries is responsible for conducting fishery resource surveys in Nantucket Sound and analyzing the collected data. This agency is the best source of information and data on the Sound's fish resources.

C. The National Fisheries Service (Woods Hole). This agency is another source of information and statistics concerning the fishery resources of the Sound.

D. Massachusetts Natural Heritage Program. This agency within EOEA has current information on the rare, endangered and special species of plants and animals in the Nantucket Sound Area.

E. Other Main Sources of Information

1. Cape Cod Museum of Natural History.
2. Cape Cod Planning and Economic Development Commission.
3. Martha's Vineyard Commission.
4. Massachusetts Audubon Society.
5. Monomoy National Wildlife Refuge.
6. Nantucket Planning and Economic Development Commission.
7. Peter Foulger Museum; Nantucket
8. Provincetown Center for Coastal Studies.
9. The United States Geologic Survey.

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Alligatorfish
American lobster
Atlantic cod
Atlantic herring
Atlantic mackerel
Atlantic menhaden
Atlantic silversides
Bay scallop
Black sea bass
Blueback herring
Bluefish
Bluespotted cornetfish
Blue runner
Butterfish
Calico crab
Channel whelk
Crevalle jack
Cunner
Flying gurnard
Fourbeard rockling
Fourspot flounder
Gray triggerfish
Goosefish
Grubby
Gulf Stream flounder
Horseshoe crab
Inshore lizardfish
Knobbed whelk
Little skate
Longfin squid
Longhorn sculpin
Lumpfish
Mackerel scad
Moonsnail
Mussel unclass.
Northern kingfish
Northern pipefish
Northern puffer
Northern searobin
Ocean pout
Ocean quahog
Orange filefish
Oyster toadfish
Planehead filefish
Pollock
Quahog
Rainbow smelt
Red goatfish
Red hake
Rock crab
Rock gunnel
Round scad
Sand lance
Scup
Sea raven
Seasnail
Short bigeye
Shortfin squid
Silver hake
Smooth dogfish
Snake blenny
Snakefish
Spider crab
Spiny dogfish
Striped anchovy
Striped searobin
Striped seasnail
Summer flounder
Surf clam
Tautog
Thorny skate
Trumpetfish
Weakfish
White hake
Windowpane
Winter flounder
Winter skate
Yellowtail

NATIONAL MARINE SANCTUARY SITE EVALUATIONS

Recommendations and Final Reports

June 7, 1983

prepared by
CHELSEA INTERNATIONAL CORPORATION
1718 P St., NW
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for

National Oceanic & Atmospheric Administration
Office of Ocean and Coastal Resource Management
Sanctuary Programs Division

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NATIONAL MARINE SANCTUARY SITE EVALUATIONS

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In addition to the 30 Resource Evaluation scientists, the Project Team was composed of the following individuals. Each demonstrated special talents and expertise in completing his or her responsibilities which are also presented below.

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Florida Middle Ground, off Florida
Shoalwater Bay - Chandeleur Sound, Louisiana
Flower Garden Banks, off Texas
Baffin Bay, Texas

NORTH ATLANTIC REGION

Management Overview
1. Resource Evaluation Team
2. Site Evaluation and Public Participation Process
3. Recommendations

Site Descriptions
Virginia - Maryland Nearshore Waters & Barrier Island Bays
Narragansett Bay & Block Island Sound, Rhode Island
Nantucket Shelf, Massachusetts
Stellwagen Banks, Massachusetts
Frenchmen's Bay/Mid-coastal Maine

SOUTH ATLANTIC REGION

Management Overview
1. Resource Evaluation Team
2. Site Evaluation and Public Participation Process
3. Recommendations

Site Descriptions
Ten Fathom Ledge - Big Rock, North Carolina
White Oak River System, North Carolina
Santee Delta, South Carolina
Port Royal Sound, South Carolina
Florida Shelf Coral gounds

WEST PACIFIC REGION

Management Overview
1. Resource Evaluation Team
2. Site Evaluation and Public Participation Process
3. Recommendations

Site Descriptions
Northern Mariana Islands
Cocos Lagoon, Guam
Papaloloa Point (Ofu Island), American Samoa
Southern Mariana Islands
Facpi Point, Guam.

ATTACHMENT A National Marine Sanctuary Site Identification Criteria

ATTACHMENT B List of Acronyms

APPENDIX I. Regional Public Participation Packages

I. SUMMARY REPORT FOR THE NATIONAL MARINE SANCTUARY SITE EVALUATION PROGRAM

SUMMARY REPORT FOR THE NATIONAL MARINE SANCTUARY PROGRAM

Concerned about mounting use and pressures on the marine environment, Congress enacted legislation in the 1970s to manage and protect our offshore areas. One such Congressional response -- the Marine Protection, Research Sanctuaries Act of 1972 -- provides a comprehensive and balanced approach for the preservation and multiple use of selected marine areas. Title III of the Act authorizes the Secretary of Commerce to designate areas of ocean and the Great Lakes waters as marine sanctuaries to preserve or restore them "for their Conservation, recreational, ecological, or esthetic values." The National Oceanic and Atmospheric Administration (NOAA) administers Title III through its Office of Ocean Coastal Resource Management, Sanctuary Programs Office (SPO).

Formation of the National Marine Sanctuaries Program resulted from this 1972 Congressional initiative. Focusing on comprehensive management and protection of diverse marine areas, the National Marine Sanctuaries Program identifies marine and Great Lakes sites of long-term resource benefit and public enjoyment. The program, not strictly regulatory in nature, represents a management tool for national marine resource development, conservation, and use. Simply stated, the program provides a balance among multiple uses of designated marine and Great Lakes areas.

Under Title 15 of the Code of Federal Regulations, Part 922 -- Marine Sanctuaries, until the September 7, 1982 publication of proposed revised rules, any person could recommend a site for consideration as a possible marine sanctuary. Those regulations set forth procedures and criteria to review sanctuary candidates for possible placement on a List of Recommended Areas (LRA). Once determined by NOAA, the LRA was published in the Federal Register with no additional public input required. As a result of this process, NOAA received an extraordinary range of site nominations, which varied substantially in size and technical supporting data. The nomination process became unwieldy; occasionally sites were nominated to prevent certain uses from occurring in a particular area. This led to Congressional and public concern over the nomination process.

In February 1982, the Chelsea International Corporation of Washington, D.C., was awarded a contract to recommend marine areas for possible placement on a Site Evaluation List (SEL). The Program Development Plan (PDP) designed by NOAA for marine sanctuaries specified that sites had to be selected and evaluated not only on their scientific and resource merits but also on their human use and management values. The objective of NOAA's contract with Chelsea was to provide NOAA with sufficient information to replace the LRAs through a new site nomination procedure that focused on the area's natural resources. In this procedure, sites would be identified by a scientific evaluation process and would be presented to the public for comment before nomination to NOAA for inclusion on its new Site Evaluation List. This process was embodied in the September 7, 1982, NOAA proposed rule.

THE DESIGNATION PROCESS

The designation process, from site identification to final approval to actual designation, is long and involved. Consequently, the Secretary of Commerce has designated only six areas since passage of the Act in 1972.

The site designation process outlined by NOAA is as follows:

1. Sites are identified by the regional resource teams,

2. Regional resource teams apply site identification criteria to each site within that region.

3. The initial list of site descriptions are approved by the regional resource team and are mailed to previously identified individuals and organizations, nationally and within the region.

4. Public comment and additional nominations are received

5. Each regional resource team recommends no more than five sites to NOAA following the close of the public comment period.

6. NOAA selects sites for placement on the SEL, which is then published in the Federal Register for comment. NOAA prepares a written analysis of how each site meets the resource evaluation criteria for future reference.

7. NOAA selects a candidate site from the SEL; in compliance with the National Environmental Policy Act an environmental analysis is made.

8. A notice of intent to prepare a draft environmental impact statement (DEIS) is published in the Federal Register.

9. A draft site management plan describing objectives and possible regulatory actions for the area is prepared.

10. One or more regional meetings are held to solicit government and public comment on the selected site and its proposed management plan. Appropriate revisions are then completed and reviewed with interested parties, and any additional meetings are held with relevant Federal agencies.

11. A public hearing is held on the DEIS and draft management plan no less than 30 days after notice in the Federal Register; written comments are accepted for 45 days after date of notice.

12. A final environmental impact statement (FEIS) is prepared and distributed for final comment.

13. Final consultation occurs with Federal agencies and state officials.

14. The Secretary of Commerce, upon approval of the President, designates the area as a National Marine Sanctuary.

15. The designation is effective unless the Governor of a State with waters lying within the boundary of the site objects to its designation, or both Houses of Congress adopt a concurrent resolution of disapproval within 60 days of continuous Congressional session.

SCIENTIFIC RESOURCE EVALUATION TEAMS

As contracted, Chelsea International was responsible for completing the resource evaluation efforts and for drafting the recommendations to NOAA of areas worthy of sanctuary designation. To carry out this charge, Chelsea established teams of nationally recognized marine scientists for eight regions whose boundaries approximate those of the Regional Fishery Management Councils specified in the Magnuson Fishery Conservation and Management Act of 1976. For the SEL process, the boundary between the North and South Atlantic regions was Cape Hatteras, North Carolina; the boundary between the South Atlantic and Gulf of Mexico regions was U.S. Route 1 in the Florida Keys.

The scientific resource evaluation teams were comprised of the following scientists:

Caribbean Region

Dr. Manuel Hernandez-Avila
Team Leader
Chairman, Department of Marine Sciences
University of Puerto Rico
Mayaguez, Puerto Rico
(Physical Oceanography)

Dr. John Ogden
Director, West Indies Laboratory
Fairleigh Dickinson University
St. Croix,
U.S. Virgin Islands
(Marine Biology)

Eastern Pacific Region

Dr. Paul Rudy, Team Leader
Director, Institute of Marine Biology
University of Oregon
Corvallis, Oregon
(Marine Biology)

Dr. P. Dee Boersma
Director, Institute of Environmental Studie
University of Washingt
Seattle, Washington
(Zoology)

Dr. Joel W. Hedgpeth
Marine Biologist
Oregon State University (retired)
Santa Rosa, California
(Biological Oceanography)

Dr. June Lindstedt-Siv
Environmental Scientis
Atlantic-Richfield Co.
Los Angeles, Californi
(Marine Biology)

Dr. Elizabeth Venrick
Scripps Institution of Oceanography
La Jolla, California
(Marine Biology)

Great Lakes Region

Dr. A. M. Beeton, Team Leader
Director, Great Lakes & Marine Water Center
University of Michigan
Ann Arbor, Michigan
(Zoology)

Dr. Charles E. Herdend
Director, Sea Grant Program
Ohio State University
Columbus, Ohio
(Geology)

Dr. H. J. Harris
Coordinator, Green Bay Project
Sea Grant Program
University of Wisconsin
Green Bay, Wisconsin
(Zoology)

Gulf of Mexico Region

Dr. Thomas Bright, Team Leader
Department of Oceanography
Texas A&M University
College Station, Texas
(Marine Biology)

Dr. William G. McIntire
Associate Dean, Center for
Wetland Resources (retired)
Louisiana State University
Wofford Hts., CA
(Coastal Geology)

Dr. David A. Gettleson
Continental Shelf
Associates
Tequesta, Florida
(Marine Biology)

Dr. James P. Ray
Shell Oil Company
Houston, Texas
(Marine Biology)

North Atlantic Region

Dr. Maurice Lynch, Team Leader
Virginia Institute of Marine Sciences
College of William and Mary
Gloucester Point, Virginia
(Marine Biology)

Dr. Jeffrey Levinton
Dept. of Ecology and Evolution
State University of New York
at Stony Brook
Stony Brook, New York
(Marine Biology)

Dr. H. Perry Jeffries
(replaced Dr. Bostwick Ketchum)
Graduate School of Oceanography
University of Rhode Island
Kingston, Rhode Island
(Marine Biology)

Dr. Bostwick Ketchum
Professor Emeritus
Woods Hole Oceanographic
Institute
Woods Hole, Massachusetts
(Marine Biology)

Dr. Walter Adey
Director, Marine Systems
Laboratory
Smithsonian Institution
Washington, D.C.
(Marine Biology)

South Atlantic Region

Dr. Vernon J. Henry, Team Leader
Chairman, Geology Department
Georgia State University
Atlanta, Georgia
(Marine Geology)

Dr. F. John Vernberg
Director, Belle Baruch
Institute for Marine
Biology
University of South
Carolina
Columbia, South Carolina
(Marine Biology)

Dr. Dirk Frankenberg
Director, Marine Sciences Program
University of North Carolina
Chapel Hill, North Carolina
(Marine Biology)

Dr. Harold Wanless
Professor, Marine Geology
University of Miami
Miami, Florida
(Marine Geology)

Western Pacific Region

Dr. Roy Tsuda, Team Leader
Dean of Graduate School
and Research
University of Guam
Mangilao, Guam
(Botany)

Dr. Richard C. Wass
Office of Marine
Resources
Pago Pago, American Samoa
(Marine Biology)

Dr. E. Alison Kay
Professor of Zoology
University of Hawaii
Honolulu, Hawaii
(Zoology)

Alaska Region

Dr. Vera Alexander, Team Leader
Director, Institute of
Marine Sciences
University of Alaska at Fairbanks
Fairbanks, Alaska
(Marine Biology)

Dr. Lewis J. Haldorson
School of Fisheries
University of Alaska at
Juneau
Juneau, Alaska
(Fisheries Biology)

Dr. Donald F. Keen
ARCO Alaska, Inc.
Anchorage, Alaska
(Marine Biology)

Dr. Robert Weeden
Resource Management
School
University of Alaska at
Fairbanks
Fairbanks, Alaska
(Zoology)

The teams, comprised of independent scientists with knowledge of the values and uses of coastal waters within their region, were charged to:

- Identify and recommend areas within their region, based on NOAA's scientific selection criteria, for consideration as potential sanctuary sites.

- Acquaint State and local governmental entities and regional interest groups with the site selection process.

- Recommend no more than <u>five</u> sites in the region to NOAA following the public comment period.

To support these teams, Chelsea and the technical staff of the Research Planning Institute, Inc. (RPI) coordinated the program and complemented the efforts of the teams. Chelsea's Project Manager and two Program Managers were in frequent contact with the team leaders, NOAA officials, and others concerned. One Program Manager was responsible for the North Atlantic, South Atlantic, Gulf, and Caribbean teams; the other Program Manager coordinated efforts with the Alaska, Great Lakes, East Pacific, and West Pacific teams. Chelsea and RPI support included meeting organization, distribution of materials, and technical expertise for drafting of site descriptions and reports.

RESOURCE EVALUATION CRITERIA

As specified by NOAA's Program Development Plan (PDP), the teams used NOAA's scientific criteria in their evaluations and deliberations. The criteria, which address characteristics of particular significance to the National Marine Sanctuaries Program, are grouped in the following four categories with accompanying subheadings:

Natural Resource Values

Regional representation
Subregional representation
Community representation
Biological productivity
Biotic character/species representation
Species maintenance
Ecosystem structure/habitat features

Human Use Values

Fishery resources of recreational importance
Fishery resources of commercial importance
Ecological/esthetic resources of importance for recreational activities other than fishing
Research opportunity
Interpretive opportunity
Historical, archaeological, or paleontological importance

Potential Activity Impacts

Activities that may arise in a specific area, including:

Vessel traffic
Aircraft overflights
Commercial or recreational fishing
Other recreational sports
Waste disposal
Research
Dredging
Anchoring
Salvage operations
Oil and gas activities

Management Concerns

Relationship to other programs
Management of a conservation unit
Surveillance and enforcement
Economic considerations
Accessibility

After determining which criteria were met, the teams tabulated their results using a Site Evaluation Matrix. A low, moderate, high, or unknown value was given to each individual criterion met. Those sites which consistently received low values were given a "low priority" assessment and eliminated; those which consistently received high values were given a "high priority" assessment and recommended for further consideration. Appendix A provides the guidelines used in the priority value rating.

SITE NOMINATION PROCESS

The site nomination process began in March 1982 with two team leader orientation meetings in Washington, D.C. NOAA's Sanctuary Program Office (SPO) extensively briefed Chelsea staff and the team leaders on program status, desired goals, and the site evaluation criteria. Chelsea was asked to present NOAA with a revised plan on an accelerated schedule instead of the 15-month plan called for in the initial Request for Proposal. The accelerated plan required two meetings in each region -- the first to identify sites meeting the necessary criteria and the second to select and recommend final sites for NOAA following the public comment period.

To facilitate the delivery of recommendations to NOAA in the requested 12 months, meeting schedules were rigid. The regional resource evaluation teams were provided NOAA's PDP and criteria and briefed on the planned process by the Team Leader. The team members were asked to nominate areas for possible consideration at the first regional meeting. These nominations were to be based on personal knowledge, research, and contacts with colleagues familiar with the resources of the region. Members were encouraged to discuss candidate sites with others interested or knowledgeable of the area. Detailed documentation of the resources and values of a nominated area was mandated for the meeting.

First Regional Team Meetings

Chelsea arranged two-day meetings for team members to discuss potential sites. No limitation was placed on the number of areas for suggestion, but each team had to consider the sites within the region that were on the LRA and each member was aware of the charge for final recommendation of <u>five</u> sites to NOAA for inclusion on its SEL.

One team meeting per week was held from April 15, 1982, to June 9, 1982. At these first meetings, discussion centered on site description, resource evaluation, the reason for sanctuary nomination, and other pertinent information. Following each regional team meeting, the RPI technical staff prepared detailed site descriptions, which presented the technical merits of each site, identified resource or management issues, and provided a list of references

Public Participation Process

Of critical concern to NOAA and the team members was public participation and comment in the sanctuary nomination process. The public was encouraged to comment on the candidate sites identified by the teams that met NOAA's scientific criteria.

This public participation was particularly important to the success of the program because of certain constraints:

- o The large geographical area covered by each of the eight regions.
- o The small number of team members for each region.
- o The lack of adequate resources to hold multiple public hearings in each region.

Throughout the site identification and evaluation process, continual contact with individuals, groups (public and commercial), government agencies potentially interested in marine sanctuaries was made. Media and telephone interviews were conducted with interest groups, such as fishermen's associations, oil and gas associations, and government officials. Moreover, significant outreach activities were made in areas where confusion or controversy surfaced over individual sites or the process involved.

The packages of material provided for review and comment were carefully structured to provide as much information as possible and to ensure comparable comments among the various regions. The packages contained a brief description of the marine sanctuary program; a request for comments on any or all of the sites; and details on the manner in which additional areas could be recommended for consideration.

Mailing lists were solicited from myriad sources -- State coastal zone offices, State Governors, environmental groups, industry, Leagues of Women Voters, Chambers of Commerce, State agencies, and others. NOAA's Administrator wrote to the Governor of each coastal State requesting a liaison to coordinate responses from State and local governmental units. The regional mailing lists were then sent for review to team members, State liaisons, State coastal zone representatives, and NOAA personnel.

About 30 days after each initial team meeting, the regional site descriptions were sent to each name on the respective mailing lists and to 82 national organizations and agencies. A deadline of 45 days was set for comment, with 30 days provided for submission of new nominations. More than 3,600 site description packages were distributed, and over 1,000 responses and 27 site nominations were received and sent to the team members. (See Table 1.) Chelsea then prepared a matrix of responses for each site which was provided to the regional team members along with copies of all comments and nominations.

Team members gave serious consideration to the public comments and recommendations received in their evaluation of potential marine sanctuaries. Each team read the comments, talked to interested individuals, groups, or officials, and developed a priority listing based on the sites previously identified and those identified public.

Second Regional Team Meetings

Beginning in September 1982 and ending in October 1982, the second team meetings followed the public comment and site nomination period. These meetings focused on ranking sites for submission of the final five to NOAA.

A problem arose -- five teams (Great Lakes, Gulf of Mexico, North Atlantic, South Atlantic, and West Pacific) had received nominations from the public which they believed worthy of full consideration for nomination. In each case, the public nominator provided comprehensive scientific and resource information, and, in some cases, presented data not previously available to the team members. Although each of these five teams took a slightly different approach in the final selection, each conducted additional discussions and evaluations of the sites considered worthy of additional consideration. In those regions where the final list of five recommended sites included one of these public-recommended nominees, NOAA agreed to another round of comment on the new site descriptions. The revised packages were sent to individuals on the original mailing list of each of the five regions with a response request within 30 days. Because of particular circumstances in the North Atlantic region, a third mailing was conducted, which is described in the chapter on the North Atlantic region.

Following this second round of public comment and evaluation, the regional resource evaluation teams made their final selection of 33 sites to recommend to NOAA for inclusion on its SEL.

It must be noted that NOAA asked Chelsea to terminate its efforts in the Alaska region on November 2, 1982. During the public comment period for Alaska, numerous concerns arose about the concept of a sanctuary, possible restrictions, the size and number of sites, and the perceived lack of public participation raised by Alaskan fishermen and public officials. Although Chelsea attempted to address these concerns through extensive outreach efforts, communication difficulties, timing, and Alaskan Congressional requests halted the process. Therefore, the final list or recommendations does not contain sites within the boundaries of the Alaskan region.

Final regional reports reflect member sensitivity to the conflicting interests of such a process and to the public perceptions of such deliberations. Boundaries were particularly controversial, and several teams stressed the need for NOAA, state and local officials, and private interests to evaluate the boundary question once the sites reached active candidate status. Teams also highlighted management issues and possible recommendations.

Team Recommendations

The regional resource evaluation teams recommended the following sites to NOAA for inclusion on its SEL:

RECOMMENDED AREAS

Caribbean Region

Cordillera Reefs, Puerto Rico
East End, St. Croix, U.S. Virgin Islands
Southeastern St. Thomas, Virgin Islands

East Pacific Region

Washington State Nearshore
Cortez & Tanner Banks, off California
Morro Bay, California
Heceta-Stonewall Banks, Off Oregon
Western Washington Outer Coast

Great Lakes Region

Western Lake Erie Islands & Sandusky Bay, Ohio
Green Bay (Lake Michigan), Wisconsin
Lake Superior (including Apostle Islands & Isle Royal) Michigan and Wisconsin
Cape Vincent (Lake Ontario), New York
Thunder Bay (Lake Huron), Michigan

Gulf of Mexico Region

Big Bend Seagrass Beds, off Florida
Florida Middle Ground, off Florida
Shoalwater Bay - Chandeleur Sound, Louisiana
Flower Garden Banks, off Texas
Baffin Bay, Texas

North Atlantic Region

Virginia - Maryland Nearshore Waters & Barrier Island Bays
Narragansett Bay & Block Island Sound, Rhode Island
Nantucket Shelf, Massachusetts
Stellwagen Banks, Massachusetts
Frenchmen's Bay/Mid-coastal Maine

South Atlantic Region

Ten Fathom Ledge - Big Rock, North Carolina
White Oak River System, North Carolina
Santee Delta, South Carolina
Port Royal Sound, South Carolina
Florida Shelf Coral gounds

West Pacific Region

Northern Mariana Islands
Cocos Lagoon, Guam
Papaloloa Point (Ofu Island), American Samoa
Southern Mariana Islands
Facpi Point, Guam.

THE REPORT

The following chapters contain the individual regional reports which discuss site identification, evaluation, and the recommendation process for the region. Issues addressed by the team are presented as well as methods and reasons for site selections. A final site description and map for each recommended area also is included.

NORTH ATLANTIC REGION

MARINE SANCTUARY SITE EVALUATION LIST
NORTH ATLANTIC REGION

MANAGEMENT OVERVIEW

1. Resource Evaluation Team

The North Atlantic resource evaluation team was initially comprised of four marine biological scientists, one each from Massachusetts, New York, Virginia, and the Smithsonian Institution in Washington, DC. The team leader was Dr. Maurice P. Lynch of the Virginia Institute of Marine Sciences, College of William and Mary. The other team members were Dr. Bostwick ("Buck") Ketchum, Professor-Emeritus from Woods Hole Oceanographic Institute; Dr. Jeffrey Levinton of the Department of Ecology and Evolution, State University of New York at Stony Brook, and Dr. Walter Adey, Director of the Marine Systems Laboratory of the Smithsonian Insitution.

At untold loss to the marine science community, Buck Ketchum died on July 15, 1982. He was replaced on the resource evaluation team by Dr. H. Perry Jeffries of the Graduate School of Oceanography, University of Rhode Island. Dr. Jeffries is also a biologist. During the site evaluation process, both Drs. Lynch and Jeffries made several contacts within their respective states with state government officials, environmental groups, and other marine scientists.

2. Site Evaluation and Public Participation Process

The team met on April 26-27, 1982, in Stony Brook, NY, for its initial consideration of potential North Atlantic sanctuary sites. Five potential sites were proposed after the team had evaluated 27 possible Marine Sanctuary sites, including all of the North Atlantic areas that were on NOAA's List of Recommended Areas (44 Fed. Reg. 62552, Oct. 31, 1979). Descriptions of the five sites were mailed to 250 individuals and groups, including 82 national organizations and Federal agencies, for comment. The initial five sites were:

NA-1. Isles of Shoals, ME and NH. This site encompassed the waters within a 3-mile radius of the Isles of Shoals, which are about 15 mi southeast of Portsmouth, NH, and lie astride the Maine - New Hampshire border.

NA-2. Plymouth Bay, MA. This 25 sq mi site included Plymouth Bay and the adjacent nearshore waters out to about one mile from shore.

NA-3. Barnstable Harbor, MA. This 18 sq mi Cape Cod site included Barnstable harbor and the adjacent waters out to about one mile from shore.

NA-4. Nantucket Shelf, MA and offshore. This was a 3-site proposal, including the 10 sq mi Nantucket Harbor, 345 sq mi of Nantucket Shoals, and 136 sq mi around Hydrographer Canyon.

NA-5. Virginia Barrier Island and Bays, VA. About 300 sq mi of waters surrounding the barrier islands of Virginia, from Chincoteague Inlet south to Fisherman's Island, were included in this proposal.

By the comment deadline of August 13, 1982, Chelsea had received 52 responses commenting on one or more of the five sites (75 responses were ultimately received). By the September 13 nomination deadline, six sites had been suggested by the public. Those sites were:

1. All Submarine Canyons off Georges Bank
2. The "hole in the Doughnut" area of Federal waters between Cape Cod and Nantucket Island
3. Stellwagen Bank, off MA
4. Narragansett Bay (3 sites), RI
5. Great Bay, NJ
6. Assateague Island, MD

The resource evaluation team met again on September 23, 1982, at the University of Rhode Island. At that meeting the team reviewed the public comments on their first five proposals, as well as the new nominations. The team concluded that two of the new nominations (Stellwagen Bank and Narragansett Bay) met the Marine Sanctuary criteria and that public comment should be solicited on those two proposals. They also reevaluated their original Virginia Barrier Islands and Bays proposal in light of the Assateague Island nomination, and determined that a new proposal should be constructed from those two. The team also reconsidered its original 3-site Nantucket Shelf proposal and decided to replace Nantucket Harbor with the "Hole-in-the-Doughnut" proposal received from the State of Massachusetts, and to replace Hydrographer Canyon with Oceanographer Canyon. The team was not of the opinion that Great Bay, NJ, should be proposed as a Marine Sanctuary, and they did not believe that there was any reason to include all three major submarine canyons rather than a single one. Four more site descriptions were then prepared for public comment, which were mailed to the original list for comment by November 22, 1982. The four new (or modified) sites were:

NA-4 Nantucket Shelf (modified)
NA-5 Virginia - Maryland Nearshore Waters and Barrier Island Bays (Modified)
NA-6 Stellwagen Bank
NA-7 Narragansett Bay and Block Island Sound, RI

In response to the second request for public comments, Chelsea received 92 responses, most of which were comments in favor of NA-5, the combined Assateague Island - Virginia Barrier Islands proposal.

2.1. The Maine Problem

At the beginning of the site evaluation process, Chelsea and the North Atlantic team were instructed not to consider the State of Maine because two contracts for Marine Sanctuary site evaluation were already underway in Maine. One contract had been let to the Marine Systems Laboratory of the Smithsonian Institution, and that project's principal investigator, Dr. Walter Adey, had since been named as a member of the resource evaluation team. The other contract had been let to the Maine Department of Marine Resources, headed by Dr. Spencer Appolonio. At an initial meeting of team leaders and NOAA personnel, the team leader, Dr. Maurice Lynch, was told that both contracts would produce nominations for Maine sites by the time of the second team meeting.

Neither contractor produced a recommendation by the time of the team's second meeting on September 23, 1982, and the entire coast of Maine might have been left out of the site evaluation process. Both contractors were then instructed by NOAA to submit site nominations immediately, so that the resource evaluation team could evaluate Maine sites along with the rest of the North Atlantic region. Those descriptions were received in early December, and were mailed out to the North Atlantic mailing list (except Virginia addressees) on December 17, 1982, with a 30-day deadline for comment. The two sites were:

NA-8. Frenchmen's Bay and the Gulf of Maine. A 407 sq mi site is next to Acadia National Park and extends several miles offshore to surround Mt. Desert Rock.

NA-9. Mid-coastal Maine. This 430 sq mi site lies to the west of Frenchmen Bay and takes in the waters around several offshore islands, three estuaries, and two bays.

The Maine public comment exercise turned out to be explosive. As the January 17 deadline approached, NOAA extended the comment period another 30 days, to February 17, 1983. Throughout the 60-day comment period, Chelsea periodically sent copies of all correspondence to the team members, with the final batch going to the team leader at the close of business on February 17. On or about February 1, and again on February 18, 1983, Dr. L polled the other team members -- with the exception of Dr. -- by telephone to produce the final list of recommendation NOAA.

3. Recommendations

3.1. The North Atlantic Team's Approach

The North Atlantic region contains two distinct biogeogra regimes; the Virginian and the Acadian. These two regimes in the area south of Cape Cod, and the transition area itsel as important as the two major regimes. The resource evalua team sought to identify sites which would represent the Aca and Virginian regimes, as well as the transition zone. At same time that they were evaluating "representative" sites, team tried to identify potential "unique" sites. The believes that their final five recommendations meet both of t objectives.

3.2. Site Selection

The North Atlantic resource evaluation team recommends the fol ing five sites to NOAA for placement on the Site Evaluation L Without attempting to prioritize them, they are:

1. Virginia - Maryland Nearshore Waters and Barrier Island B VA and MD
2. Narragansett Bay and Block Island Sound, RI
3. Nantucket Shelf
4. Stellwagen Bank
5. Frenchmen's Bay, ME

As part of the final regional report, RPI has prepared a se short descriptions of each site, including a map showing recommended boundaries of each proposed Marine Sanctuary. balance of this part of the report contains highlights of team's rationale for choosing each site, and comments on spec management issues that came to the team's attention during process.

3.2.1 Virginia - Maryland Nearshore Waters and Barrier Island Bays, VA and MD.

This is the recommended Virginian site. It includes 1200 sq mi off the coasts of Maryland and Virginia, and extends 10 mi offshore. When the site was first put forward with only the Virginia offshore area included, it elicited 31 comments, 16 in favor, 8 opposed and 7 neutral. The local units of government opposed the proposal, but the State of Virginia officially adopted a "wait-and-see" attitude. At the same time, another 9 commenters recommended inclusion of the waters around Assateague Island (MD). It would be a mistake to take public support for granted on this site but the resource evaluation team believes that a Virginian biogeographic site should be on the final SEL.

When the Assateague nomination was added to the Virginia Barrier Islands proposal, the public response was overwhelmingly favorable. 64 commented, with 52 in support, 4 opposed and 8 neutral. The State of Maryland endorsed the new site, and Virginia was still willing to give it fair consideration. Local Virginia governments, however, are still opposed.

3.2.2. Narragansett Bay and Block Island Sound, RI

This site is the nearshore "anchor" in the biogeographic transition region between the Acadian and the Virginian regimes. Strong local support for this proposal was evidenced at the team's second meeting, where the nomination was defended by the new team member, Dr. Perry Jeffries of the University of Rhode Island. Although the site is entirely in State waters, it appears to have the support of the State of Rhode Island.

3.2.3. Nantucket Shelf

At the first team meeting, there was some interest in creating a "swath" sanctuary that would extend from Cape Cod to the southeastern edge of Georges Bank. This would have encompassed a large part of the biogeographical transition zone. In an effort to produce a manageable recommendation, the team proposed a nearshore site (Nantucket Harbor), a site on the shelf (Nantucket Shoals), and one of the canyons at the edge of the shelf (Hydrographer).

Between the two team meetings, the State of Massachusetts proposed the Federal waters between Cape Cod and Nantucket Island (the "Hole-in-the-Doughnut") as well as Great South Channel to the east of Nantucket Shoals. Cape Cod fishermen also asked the team leader to move the Nantucket Shoals boundary eastward to take in Great South Channel, which maintain is a major migratory route for commercial species.

Both of these suggestions were positively received, and the team made the appropriate changes at their second meeting. Massachusetts argues that their "Ocean Sanctuaries" under State law provide all of the protection necessary for Nantucket Harbor, and that only the Federal waters remain unprotected at this time. The team accepts the premise that the State Ocean Sanctuary statute functions as intended, and believes it would be presumptuous for the Federal Government to overlay that protection with yet another layer of regulation.

The rationale for initially picking Hydrographer Canyon rather than the better-studied Oceanographer Canyon at the first team meeting, was that it lay in a straight line drawn through the other two pieces of the team's initial proposal. At the second meeting the team agreed that they had no reason for selecting one over the other, but they did reconsider their earlier decision, and concluded that the extra attention paid to Oceanographer over the years may indicate that Oceanographer Canyon has more, or more interesting, resources than Hydrographer. Based upon this reasoning, the team recommends Oceanographer Canyon as part of the final Nantucket Shelf proposal.

The original proposal resulted in 22 comments, 14 supporting, 4 opposing and 4 neutral. The modified version elicited 17 responses, 10 in support, 1 opposing and 6 neutral.

3.2.4 Stellwagen Bank

This is a fairly large (480 sq mi) site, to the north of Cape Cod, that is known for its summer population of humpback, fin, minke, and northern right whales. It is adjacent to U.S. Army Corps of Engineers dredged material disposal site, which poses the only real conflict for Marine Sanctuary designation. Even that conflict appears to be a small one, hopefully corrected by trimming the northwest boundary of the proposed sanctuary.

Twenty-nine responded to the nomination, with 13 in support, 2 opposed and 11 neutral. Most of the latter were uncertain how the program worked or what the effect would be on commercial fishing. The Gloucester Fisheries Association and Gloucester Fisheries Commission expressed opposition only if commercial fishing would be affected. The Massachusetts Office of Environmental Affairs, the Maine Department of Marine Resources and the Maine State Planning Office supported the proposal.

Some of the coastal communities are apprehensive about the potential designation of Stellwegen Bank as a Marine Sanctuary, but that is probably a result of the usual concern that fishing could be prohibited in a sanctuary. This site is the only one selected by the North Atlantic resource evaluation team as a "special," rather than representative, site.

3.2.5. Frenchmen's Bay, ME

The resource evaluation team was of the opinion that an Acadian site should be placed on the Marine Sanctuary Site Evaluation List. Of the two sites recommended to the team, the Frenchmen's Bay-Gulf of Maine site was the preferred site based upon species representation and overall representation of the Acadian biogeographic province. [The resource evaluation team notes that Dr. Walter Adey was excluded from this decision, in light of the fact that he was the Principal Investigator on the NOAA contract that recommended Frenchmen's Bay.]

There was a tremendous response to this proposal - a total of 1,291 expressed their strong feelings, of which only 55 were supportive and 3 neutral. Environmental groups were unanimous in their support, while the fishing industry (with one exception) was unanimously opposed. Local governmental units were also opposed, as were state representatives from the area.

Early responses to the proposal were supportive. However, a substantial petition and post-card attack was organized in opposition to the proposal, which produced approximately 150 preprinted post-cards and over 1,000 signatures on various petitions. Individual letters of opposition (other than the post-cards) came from 8 fishermen and 16 others. The towns of Sullivan, Tremont and Bar Harbor officially opposed the designation, as did the Hancock County Planning Commission. The Mid-Atlantic Fisheries Development Foundation supported the proposal, so long as commercial fishing activities continued.

The team, in spite of the opposition, recommends that NOAA place Frenchmen's Bay and the Gulf of Maine on the SEL. In the likely event that the site cannot garner the level of public support that would be necessary in order to go forward, the North Atlantic resource evaluation team recommends that the Mid-Coastal Maine site appear on the final Site Evaluation List. The dominant consideration remains that of securing at least one Acadian site on the final SEL. For this reason, both site descriptions were prepared by RPI and are made part of the final report.

PRELIMINARY CANDIDATE
MARINE SANCTUARY SITE EVALUATION

I. SITE LOCATION AND NAME:

A. SITE NAME: Nantucket Shelf

B. LOCATION: (NORTH ATLANTIC REGION)

1. LATITUDE/LONGITUDE: 40° to 41°30' N, 68° to 70°30' W

2. DESCRIPTION: The proposed Nantucket Shelf sanctuary site, totaling 1805 mi² (4650 km²), is a series of dissimilar, biologically rich habitat types associated with and influenced by the circulation and migration patterns unique to the Georges Bank region--a biogeographic transition zone between the northern Acadian and southern Virginian provinces. Habitats included are open bay (Nantucket Sound), nearshore open ocean and shoals (Nantucket Shoals), and shelf-edge submarine canyon (Oceanographer Canyon). The Nantucket Sound site is in Federal waters between Nantucket Island and Cape Cod, Massachusetts, and its boundaries are contiguous with the Massachusetts Ocean Sanctuaries. The Nantucket Shoals and Oceanographer Canyon sites lie wholly within Federal waters off the coast of Massachusetts. A major upwelling of cold, nutrient-rich water extending along the eastern edge of the shoals serves as a temperature barrier for warm-water species to the south and is responsible for the notably high productivity exhibited by this area. The Nantucket Shelf has been extensively influenced by glacial processes (i.e., forming Nantucket Island and adjacent features). Tidal range is about 3 ft (1 m). Total area of each portion of the potential sanctuary is: Nantucket Sound 80 mi² (200 km²); Nantucket Shoals 1000 mi² (2590 km²); and Oceanographer Canyon 100 mi² (250 km²).

II. RATIONALE FOR CONSIDERATION AS A SANCTUARY

A. DOMINANT CONSIDERATIONS

1. The area contains distinctive ecological, recreational, historic, and aesthetic resources that form the basis of the predominant economic pursuits of the area: fishing and tourism.

2. The area supports the economically valuable commercial and recreational fisheries of the area which have traditionally been a social and economic mainstay for many Cape and Island communities.

3. The area is of exceptional value for its contribution to the heritage of the United States, forming an integral part of the maritime tradition of this country.

4. Proposed Marine Sanctuary designation would extend into Federal waters the management/protection activities already offered by the Massachusetts Ocean Sanctuary Act within State waters.

5. The research opportunities within the proposed site are high, offering potential in biology, oceanography, geology, and meteorology.

B. SITE EVALUATION NARRATIVE

1. NATURAL RESOURCES

a. NANTUCKET SOUND: The richness of this transition zone ecology enhances the stability of plant life and the productivity of the estuaries in bordering coastlands that provide habitats for the many species that use the proposed Marine Sanctuary areas as nursery and feeding grounds. More than 16 species of fish and shellfish are commercially harvested in the area. The most common species found are alewife, bluefish, cod, flounder, clams, whelks, scallops, and squid. Scup, black sea bass, striped bass, and tautog are also popularly sought species.

b. NANTUCKET SHOALS: Nantucket Shoals are a series of shifting sand shoals, derived from glacially deposited sediments that have been winnowed by marine processes. Most of the shoals are found under water depths of only 25 ft (8 m). Between many of the shallow areas are channels extending 60-120 ft (18-36 m) deep. Because of the shallow and ever-shifting nature of the area, as well as strong and erratic currents, Nantucket Shoals has been responsible for numerous wrecks and loss of lives. The site includes Great South Channel.

Long-finned squid and sea herring spawn in the vicinity of the shoals. Fishes common to this area include flounders, bluefish, striped bass, pollock, tuna, Atlantic cod, and mackerel. Clams, scallops, and quahogs are found in some of the shoals' areas. These waters are well known for recreational fishing. Swordfish and white marlin are occasionally seen in the vicinity of Asia Rip. The proposed site also includes areas important to scallopers and ground fishermen, and may include some environmentally sensitive spawning areas as well. The area is a major overwintering habitat for common eiders, white-winged scoters, and other migrating sea ducks which feed on blue mussels, sand lances, and other forage fish. Humpback whales occasionally feed within the area. Marine turtles also use the area, but more research is needed to fully understand the niche they occupy.

c. OCEANOGRAPHER CANYON: Submarine canyons, in general, provide a heterogeneous environment characterized by a variety of substrate types, and because they act as conduits for the transport of material from the shelf to the abyss, filter-feeding organisms are more common than those found on the shelf. Within Oceanographer Canyon, the concentration of organisms per 100 m^2 reaches peak values of 400-450 at depths of 1300 ft (400 m) and 6000 ft (1800 m). Major faunal groups include corals (primarily alcyonarians), echinoderms, fish, and crustaceans (particularly shrimp). Tilefish and an abundance of lobsters occur in this submarine canyon. Oceanographer Canyon, in general, is one of the better studied, northeastern submarine canyons.

2. HUMAN USES

The Nantucket area is one of the most popular summer resorts on the East Coast. The high quality of the coastal waters supports a multitude of recreational activities essential to a viable tourist industry. Boating, swimming, fishing, and sightseeing enthusiasts have traditionally been lured by the area's aesthetic qualities.

The area supports significant commercial and recreational finfishing and shellfishing industries which depend upon the maintained ecological integrity and water quality of the area. Nearly 80 species of commercially important fish and shellfish occur in these waters. Black sea bass, striped bass, scup, flounder, squid, blackfish, quahog, and bay scallops are among those species which are commercially harvested locally.

The Nantucket Shelf is of exceptional value for its contribution to the maritime heritage of the United States. Since the Revolutionary War period, the area has been the location of shipyards and has served as a major shipping corridor and the home port for a large segment of America's fishing and trading industries situated along the coast. The proposed area contains a number of shipwrecks that are of historical and educational value in interpreting the maritime history of America.

Portions of the site lie on an area of the outer continental shelf which is currently being considered for oil-and-gas leasing (Lease Sale No. 82) in February 1984. Oceanographer Canyon is located in an area having high hydrocarbon potential.

The area supports a growing interest in biological and geological reasearch. The limited research performed on the canyons east and south of Nantucket indicates subtle but real differences among them in terms of current regime, habitat type, and biota. Detailed scientific study of the Nantucket Shelf complex is lacking, and therefore, the area provides a wealth of opportunities for investigating the interrelationships among the various biogeographic components. The University of Massachusetts operates Nantucket Field Station which engages in research in all aspects of the marine and coastal environments surrounding Nantucket. In addition, other educational and research institutions in the area are hosted for teaching and research purposes.

Portions of the adjacent nearshore waters are already protected and managed by the Commonwealth of Massachusetts. Relevant State programs include the Ocean Sanctuary Act, the Areas of Critical Environmental Concern Program, the Wetlands Protection Act, the Wetlands Restriction Act, and other coastal protection regulations. The management of the area is of vital concern to the State Legislature, the Massachusetts Department of Environmental Management, and the local townships. Furthermore, since the area is the object of intense commercial fishing activity, the New England Fisheries Management Council regulates fishing in the area through a coordinated fishery management plan.

III. PRINCIPAL REFERENCE MATERIAL

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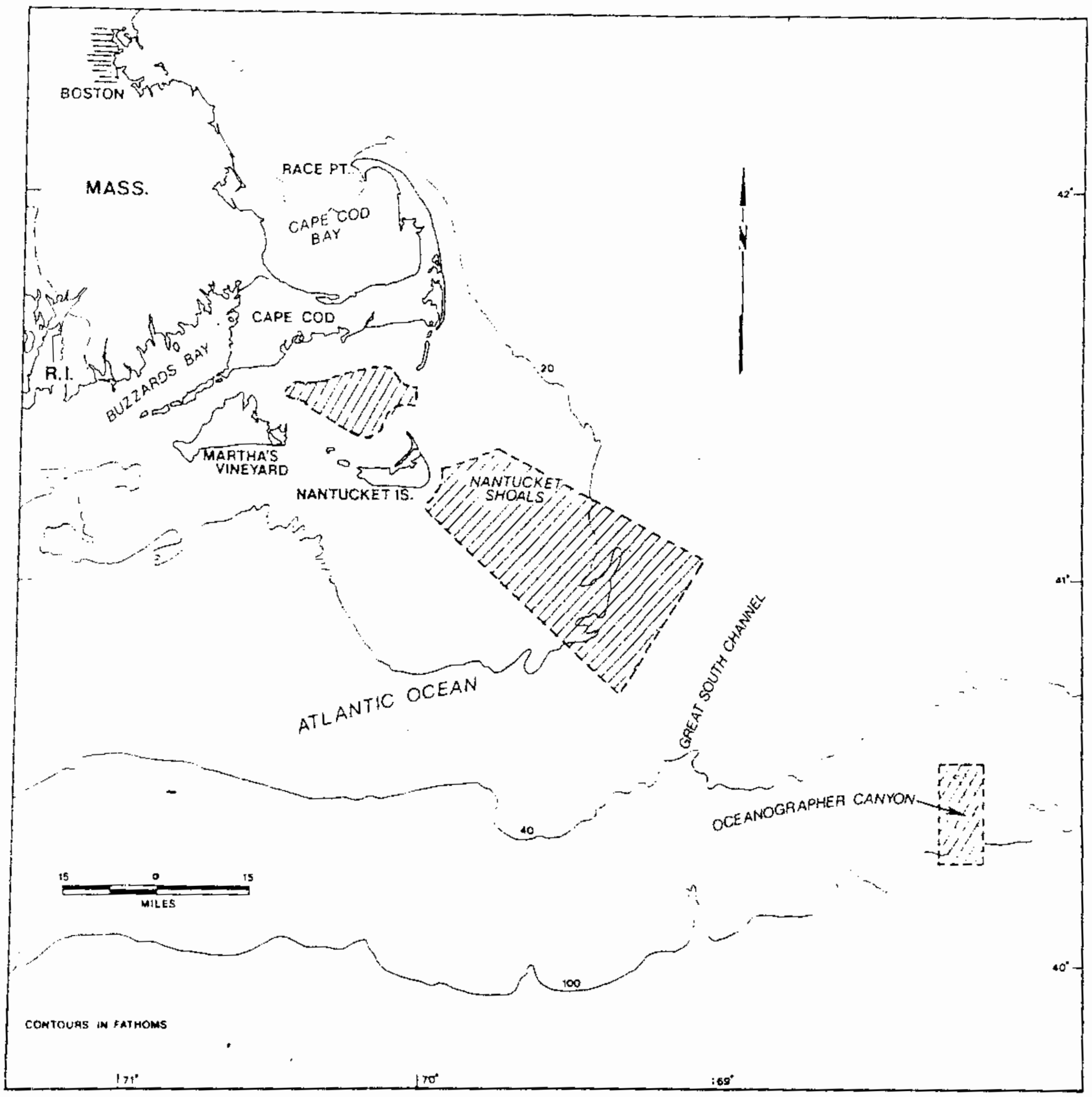

LOCATION MAP

393B

Toward an Ocean Vision for the Nantucket Shelf Region

Part I.
Review of the
Environmental Characteristics of the
Nantucket Shelf Region

Part II.
Management Options for
Resource Protection and Sustainable Uses

Provincetown Center for Coastal Studies
Provincetown, Massachusetts

January 2005

Toward an Ocean Vision for the Nantucket Shelf Region

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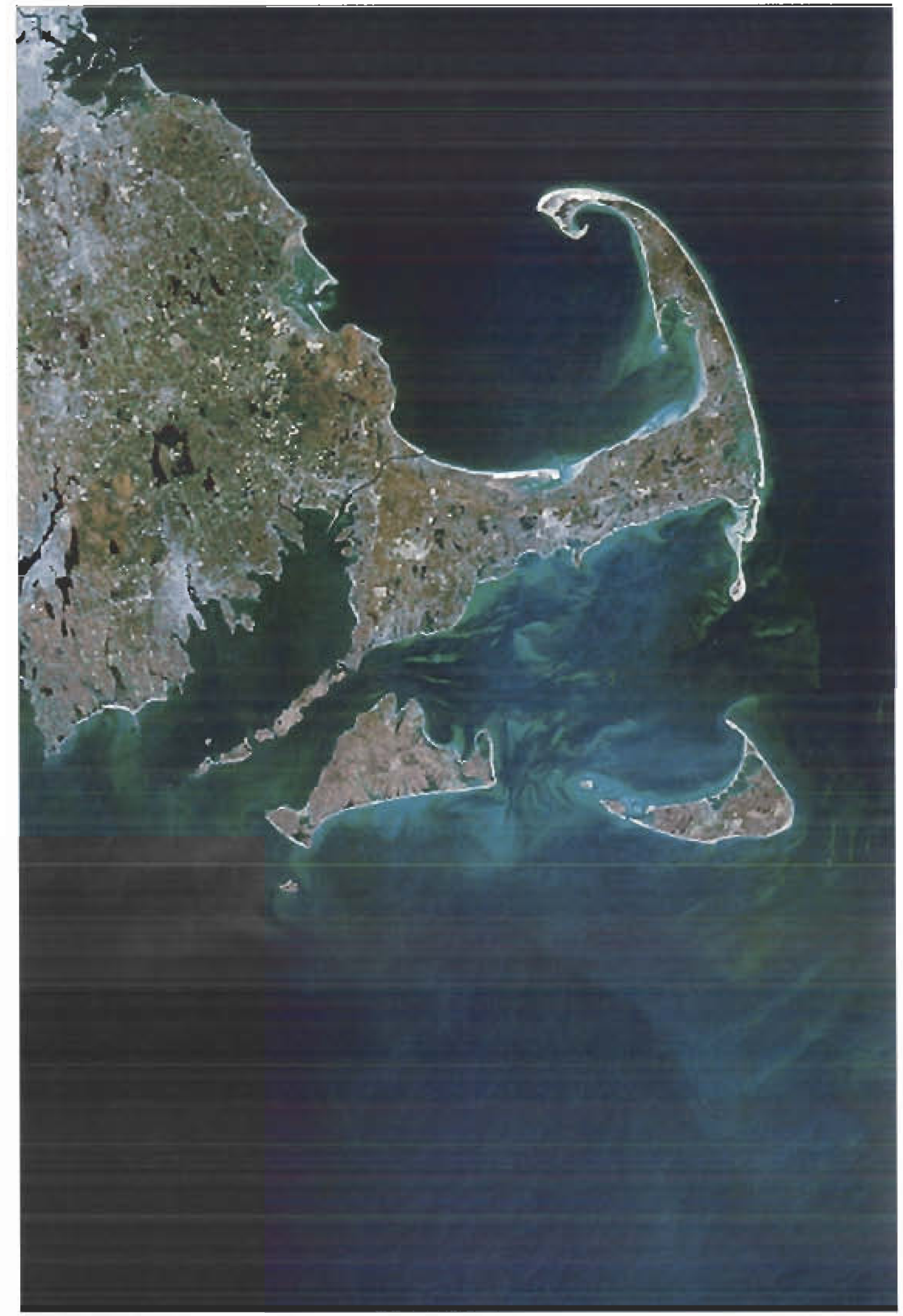

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Any opinions or recommendations expressed within this report do not necessarily represent the opinions of the people or institutions listed above.

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Toward an Ocean Vision for the Nantucket Shelf Region

EXECUTIVE SUMMARY

...."User conflicts can and do arise when incompatible activities take place in the same area. A comprehensive offshore management regime is needed for the balanced coordination of all offshore uses."

-- U.S. Commission on Ocean Policy (June, 2004)

"U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including human and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries."

-- U.S. Commission on Ocean Policy (June, 2004)

"New ocean management structures are needed to promote consistent, coordinated ocean management policies and to ensure that the geographic divisions among federal and state management authorities support rather than prevent sound ecosystem management across a variety of jurisdictions"

-- The Massachusetts Task Force Ocean Management(March, 2004)

Introduction

The ocean off the coast of Massachusetts has been the focal point for a growing number of activities and proposals in recent years. Proposals to construct the nation's first offshore wind power project have attracted recent attention; however other Massachusetts offshore waters have also been examined for potential energy facilities, offshore aquaculture sites, cable crossings, sand and gravel mining, oil and gas drilling, transportation routes and a variety of commercial and recreational activities. Ongoing issues include the implementation of fisheries management plans and marine mammal protection strategies.

The number of competing and often conflicting uses of the ocean has become problematic. Despite widespread interest in the development of renewable energy and aquaculture, proposals for these large-scale offshore facilities have revealed significant gaps in federal authority relating to the leasing of public underwater lands and permitting of offshore uses. Technological advances will undoubtedly continue to increase the number of prospective uses of ocean resources. In the face of these challenges, the ocean is an invaluable and vulnerable resource that merits a thoughtfully planned and balanced comprehensive management plan.

In 2003, the Provincetown Center for Coastal Studies issued a report entitled "*Review of State and Federal Marine Protection of the Ecological Resources of Nantucket Sound*," documenting previous initiatives to establish a clear and consistent science-based policy of resource protection that would be applicable across local, state and federal jurisdictions. Over a period of more than 30 years, specific actions toward this end have included the following:

- The state legislature in 1972 included Nantucket Sound in the Cape and Islands Ocean Sanctuary Act. This action was intended to provide full protection of the seabed and the Sound, which the state regarded as being within state jurisdiction, just as all of Cape Cod Bay is considered to be state waters. In the late 1980's, however, the U.S. Supreme Court ruled that the state had not proven its colonial claim to the entire Sound and that the waters beyond three miles from the mean low water mark were not under state jurisdiction, resulting in a "gap" in state jurisdiction in the center of Nantucket Sound.

  In 1980 the Massachusetts Attorney General and Secretary of Environmental Affairs nominated all of Nantucket Sound as a national marine sanctuary. In the nomination, various state agencies, including the Office of Coastal Zone Management and Division of Marine Fisheries, documented the region's ecological significance and its importance to such economic uses as fishing and tourism. The 1980 nomination envisioned a joint federal-state management of the sanctuary, similar in concept to the management plans now in place in the Florida Keys and California's Channel Islands.

  In response to three different oil and gas lease sales on Georges Bank proposed by the federal government in the late 1970's and early 1980's, Massachusetts repeatedly asserted its interests and role in decisions being made about the use of ocean resources off its coast.

  In 1983 a scientific panel commissioned by the National Oceanic and Atmospheric Administration included Nantucket Sound and other portions of the outer continental shelf south and east of Nantucket Sound in a short list of areas for future designation as a national marine sanctuary.

These actions were ahead of their time in recognizing the principle of *ecosystem-based management*. Ecosystem-based management of ocean and land resources is now widely accepted as the key to successful resource protection and management. Ecosystem-based management is the cornerstone of three recent major ocean public policy studies released in 2004: the Pew Oceans Commission, the U.S. Commission on Ocean Policy, and the Massachusetts Task Force on Ocean Management. In the words of the U.S. Ocean Commission:

> ***"U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including human and nonhuman species and the environments in which they live. Applying this principle will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries."***

In this study, we have taken the principle of ecosystem-based management to the next logical step for Massachusetts by defining the "relevant geographic management areas" to include the state and federal waters south and east of Cape Cod, Martha's Vineyard, and Nantucket, out to the edge of the continental shelf. We refer to these areas collectively as the **Nantucket Shelf Region**. Our definition is based on the finding that these areas are inextricably linked by large-scale physical, biological, and ecological features and processes and share many important natural and socioeconomic features.

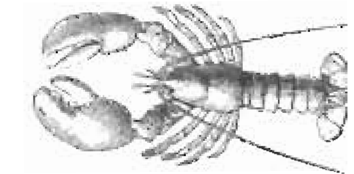
Part I of the report describes the ecological features that characterize this region and identifies issues and data gaps that warrant further scientific investigation to enhance our understanding of the region. Part II describes a number of management tools and techniques that may be useful as part of a comprehensive management scheme. In the following pages, the report describes the need for a common vision for the future of Nantucket Shelf and suggests some of the first steps in a planning process that could achieve and implement that vision.

Why Nantucket Shelf Region?

The Nantucket Shelf Region includes Vineyard Sound, Nantucket Sound, Nantucket Shoals, the continental shelf south of Martha's Vineyard, the Great South Channel, and Georges Bank. Scientific literature indicates that these areas form part of a large, shallow, coastal shelf eco-region that is characterized by a common geological origin, extremely dynamic sedimentary environment, tidally well-mixed water, high biological productivity, and unique ecological features. The Nantucket Shelf Region can be subdivided into three related ecosystems: *marine estuarine* (Nantucket Sound and Vineyard Sound), *offshore shoals* (Nantucket Shoals and Georges Bank), and *mid-shelf environment* (Great South Channel and the shelf area south of Martha's Vineyard).

The Nantucket Shelf Region serves as a dynamic transition zone between the Gulf of Maine Region to the north, which is influenced by the colder waters of the Labrador Current, and the warmer waters of the Middle Atlantic region and Gulf Stream to the south. This fundamental physical boundary between warm and cold water masses provides the setting for mixing and mingling of northern and southern species at the extreme ends of their geographic ranges, resulting in a zone of high biodiversity.

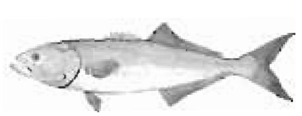
The Nantucket Shelf Region.



The Nantucket Shelf Region is one of the most heavily used ocean areas in the Northeast due to its bountiful natural resources, proximity to major population centers, and rich fishing grounds. It has a long and rich historic and cultural significance for the citizens of Massachusetts, and has high economic value for all of New England. At the same time, the area is increasingly subject to significant impacts from a myriad of human activities that threaten its quality, productivity and sustainability.

An incomplete patchwork of different federal and state ocean management jurisdictions currently exists in the Nantucket Shelf Region. The jurisdictional patchwork has a number of holes in it, in areas where preliminary (and sometimes old) scientific information suggests that the natural resources must be the same as in nearby protected areas. The absence of a single coordinating framework for ocean protection in the Nantucket Shelf Region has resulted in coastal and ocean protection that is inconsistent, with protection for some resources in one area and no protection for the same resources in an adjacent area.

This report finds that the Nantucket Shelf Region is of such ecological and socioeconomic importance that it should be the first offshore area in Massachusetts to benefit from a comprehensive ocean resources management plan. Comprehensive ocean management and protection is called for by the U.S. Commission on Ocean Policy, the Pew Oceans Commission and the Massachusetts Task Force on Ocean Management.



Development of an Ocean Resources Management Plan

The development of a successful and useful **Ocean Resources Management Plan** will largely depend upon 1) creating an effective planning process and 2) identifying key participants who can bring their knowledge, planning and management abilities to the table. A productive planning process will utilize the best available scientific information, identify and implement suitable tools, provide for the broadest public participation and input, build consensus among participants, and require commitment, cooperation and leadership from all interested parties.

One ocean management tool to consider is the designation of the Nantucket Sound Region as a "marine protected area", setting the stage for defined uses and activities. In the U.S., a Marine Protected Area (MPA), as defined by Executive Order 13158 (May 26, 2000) is "*any area of the marine environment that has been reserved by federal, state, territorial, tribal or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein.*" Many other countries use marine protected areas as an ocean and coastal management tool, and it is particularly suitable where there are many overlapping jurisdictions or where the region is large and encompasses many interests.

Although the term 'marine protected area' has only come into general use in the U.S. since Executive Order 13158, the concept includes a variety of areas created under such federal laws as the National Marine Sanctuaries Act, National Wildlife Refuge System Administrative Act, National Park Service Organic Act, and Magnuson-Stevens Fisheries Conservation and Management Act, among others. The public policy goals of each of the programs created by these laws vary, as do the management objectives within specific areas.

A national marine protected area designation could provide a comprehensive and flexible framework for the protection and management of the Nantucket Shelf Region, leading to better coordination and more effective management of its resources.

Another innovative ocean management tool highlighted in all three ocean studies is ocean zoning within the context of a marine protected area. Just as in land zoning, areas of the ocean could be identified for activities most compatible with the natural and socioeconomic values and carrying capacities of that area.

As one example, sustainable fisheries management within the Nantucket Shelf Region is highly desirable. Human uses of the area include recreational and commercial fishing and shellfishing, which are important to the local economy. The Nantucket Shelf Region also provides important nursery and migration habitat for commercially and recreationally important fish species. These socioeconomic and ecological values can both be protected through careful management for sustainable fisheries rather than prohibition. While sustainable fisheries management under the mandate of the Magnuson-Stevens Act is currently the guiding management tool for Georges Bank, only a congressional moratorium prevents exploration for oil and gas. This inconsistency of public policy represents a continuous threat to the fishery.

As a second example, areas used by endangered species for breeding and nesting should be protected as critical habitat areas. In particular, nearly the entire North American population of roseate terns passes through the Cape and Islands region and stops in Monomoy to nest and feed. While Monomoy is managed as a national wildlife refuge and more than 90% of the refuge is protected as a national wilderness area, far less protection applies to nearby state and federal waters. Terns also fly to Buzzards Bay, which is included in EPA's National Estuary Program. Existing critical habitat areas such as the Great South Channel (protected especially for the right whale) may also be linked ecologically. However, designation of the entire Nantucket Shelf Region as a critical habitat would probably not be warranted.

The Nantucket Shelf Region

Considerably more scientific and socioeconomic research is needed to develop a specific ocean zoning approach. However, an initial zoning concept for the Nantucket Shelf Region, based on available information, might include four zones as follows:

Ocean Zone 1: Including the state and federal waters south of Cape Cod and around the islands of Nantucket and Martha's Vineyard, including Nantucket and Vineyard Sounds and Buzzards Bay. This area is characterized by aesthetic and cultural values, active recreational boating and fishing, marine science and education, increasing coastal development, a coastal economy that is heavily dependent on the natural resources and scenery, and an often-disjointed network of existing coastal protected or managed areas, including the Cape Cod National Seashore, Monomoy National Wildlife Refuge and Wilderness Area, Waquoit Bay National Estuarine Research Reserve, Mashpee National Wildlife Refuge, and the Massachusetts Cape and Islands Ocean Sanctuary.

Ocean Zone 2: Nantucket Shoals and Georges Bank. These two areas share many ecological and socioeconomic features, such as: shallow sandy benthic habitat; high-energy environment; important fisheries habitat; distance from land; ecological transition area between the Great South Channel and the two shoals; moderate recreational use; high cultural value; and a hazard to shipping. Georges Bank is actively managed for fisheries and fishery closures are in effect in some areas. The threat of oil and gas drilling in Georges Bank remains.

Ocean Zone 3: Great South Channel. This area is important for both ecological reasons (feeding ground for endangered right whales and humpback whales, fish, and high productivity) and socioeconomic reasons (commercial shipping). The area contains a federal critical habitat for endangered Northern Atlantic Right Whales, and the fishery is seasonally closed.

Ocean Zone 4: Outer Continental Shelf. This area includes the large area of continental shelf south of Martha's Vineyard, Nantucket Shoals, and the Great South Channel out to the edge of the continental shelf. It is characterized by its open ocean character, highly dynamic water processes, moderate recreational value, fisheries habitat, and low to moderate risk for shipping. Relatively little is known about the ecological values of this area.

A guiding body is needed to conduct the planning process that would result in an Ocean Resources Management Plan for the Nantucket Shelf Region. This report builds on another key recommendation of the U.S. Commission on Ocean Policy by recommending the creation of a **Nantucket Shelf Regional Coordinating Committee**. The Nantucket Shelf Regional Coordinating Committee would be charged with developing a comprehensive plan for the protection, preservation, and sustainable use of the abundant resources of the Nantucket Shelf Marine Protected Area; and furthermore, to create a detailed implementation plan that emphasizes coordination of existing authorities and agencies and provides specific recommendations about additional legislative, regulatory or scientific steps that are required to fully achieve its mandate.

Various models for public process already exist, including those provided by the National Estuary Program, National Estuarine Research Reserves, and National Marine Sanctuaries. Generally, these models call for steering committees comprised of both technical and non-technical components (e.g., scientists, resource managers, coastal decision makers, citizens, businesses, resource users, etc.). The public process involves public meetings of the steering committee, stakeholders, the public, and representatives of relevant agencies.

The Nantucket Shelf Regional Coordinating Committee could be administered jointly by the federal National Oceanic and Atmospheric Administration (NOAA) and the state Executive Office of Environmental Affairs (EOEA). The active participation of the three Regional Planning Agencies (Cape Cod Commission, Martha's Vineyard Commission, Nantucket Planning and Economic Development Commission) would represent local and regional interests and highlight the land-ocean linkages. The Massachusetts Coastal Zone Management Program (CZM) within EOEA and linked closely to NOAA would bring valuable coastal and ocean planning, policy and technical expertise.

Lastly, management of the Nantucket Shelf Marine Protected Area will require both short-term and long-term process studies and long-term monitoring studies of geology, oceanography, biology, ecology, and climate. The creation of a **Nantucket Shelf Ocean Observatory** program is recommended to serve as a regional science and outreach source of information.

A great deal of work has already been completed that supports the ocean vision outlined in this report. The two national ocean commissions and state task force on ocean management have laid the groundwork for a more comprehensive ocean resources management system. The numerous existing but disjointed protected areas within the Nantucket Shelf Region signify the richness and diversity of the ecosystem. The regional planning agencies and state coastal zone management program are familiar with the socioeconomic and environmental interests of the region. However, the lack of a single unifying management and protection framework hampers coordinated management of the region.

The designation of the Nantucket Shelf Region as a marine protected area (MPA) would acknowledge its special environmental and economic values and provide a needed unifying framework; and the creation of a Nantucket Shelf Regional Coordinating Committee charged with the responsibility for developing a comprehensive ocean resources management plan, are the next two logical steps toward realizing a sustainable ecosystem-based vision for the Nantucket Shelf Region.

Part I.
Review of the Environmental Characteristics of the Nantucket Shelf Region

1. BACKGROUND

Seen from space, the great sweep of Cape Cod and its submerged banks and shoals are one of the most prominent geographic features of the Northeastern coast. Cape Cod and the islands of Martha's Vineyard and Nantucket represent only the highest points of a much larger peninsula that has been drowned by the rising sea as Ice Age glaciers melted. The submerged areas include Nantucket Shoals, Nantucket Sound, Vineyard Sound, Georges Bank, and Stellwagen Bank (Figure 1).

In fact, Nantucket Sound, Vineyard Sound, Nantucket Shoals, the Great South Channel, the continental shelf south and west of Martha's Vineyard, and Georges Bank form one continuous shallow continental shelf environment which shares a common geological origin (Emery, 1987). This larger cape, much of which is submerged now, forms much of the continental shelf off the Massachusetts coast and juts out into the North Atlantic Ocean. In this literature review, this area will be called the "Nantucket Shelf Region".

This prominent geographic feature has long been known as a major biogeographic transition zone, an area where southern species of plants and animals meet and mix with northern species. Cape Cod and nearby shelf areas form the southern boundary of the Gulf of Maine, a huge, highly productive shelf sea dominated by the cold Labrador Current flowing south from the Canadian Arctic and subject to intense cooling during the winter. The Nantucket Shelf Region also forms the northern boundary of the Middle Atlantic region that is warmed by warm core rings from by the northward flowing Gulf Stream. This region represents a major biogeographic boundary for land plants, fishes, invertebrates, and many other species of plants and animals.

Nantucket Sound has been the subject of much attention recently, due to a proposed wind farm. An earlier proposal in the 1980's to protect Nantucket Sound suffered from a lack of scientific information to support protection. Now, two decades later, due to the pressures posed by human uses of Nantucket Sound, advances in coastal research, and advances in resource management and protection, it is time to reevaluate the current state of scientific information concerning the area in order to reevaluate our management of the area.

Figure 1. The Nantucket Shelf Region. Horsley Witten Group, MASSGIS

This broad area of continental shelf most likely shares many physical, chemical and biological processes. But do we know what these are? Studies of Nantucket Sound relating to a proposed wind energy project typically focus on the area of the proposed project and on Nantucket Sound itself. Such a narrow focus may miss important features. Before one can evaluate the need for marine protection, one first needs to understand the largescale ecological and natural values of a region.

Ecosystem-based resource protection and management is not new to land managers. But for ocean managers, this is a new concept. An ecosystem-based approach first identifies the important or unique ecological features of a region. The characterization of the ecological values of a region is then used as the basis for designing appropriate measures for protection or management of these ecological features.

There are few comprehensive studies of Nantucket Sound, Nantucket Shoals, or indeed of the Nantucket Shelf Region, from the broader vantage point of an entire shelf ecosystem, such as the comprehensive studies of Stellwagen Bank (Valentine et al., 2001; Ward, 1995; Auster et al., 2001; Pett and McKay, 1990; U.S. Department of Commerce (NOAA) 1993; USGS 1998), Georges Bank (Backus, 1987; Emery, 1987; Twichell, 1987; Walsh et al., 1987; Butman, 1987; Collie et al., 1997; Franks and Chen, 2001; USGS 2001; Valentine and Lough, 1991), the Great South Channel (Kenney and Wishner, 1994) or the Gulf of Maine (Brooks, 1992; Christensen, 1989; Durbin et al., 1994; Oldale et al., 1973; Greenberg, 1983; Bigelow, 1927). Information gaps are significant, and thus a review of scientific information concerning important natural features and processes of this area must be based upon comparison with nearby better-studied areas, inference or extrapolation based on scientific knowledge of similar processes or features elsewhere. Nevertheless, there are distinctive features of the Nantucket Shelf Region which deserve to be considered for management or protection.

Part I of this report is meant to provide an objective review of the state of scientific knowledge concerning the Nantucket Shelf Region. The goals of Part I are to:

- Review and summarize existing scientific knowledge concerning the major physical, biological and ecological processes of the Nantucket Shelf Region;
- Identify data gaps and evaluate their significance; and
- Provide a factual, objective basis for further discussion of the values of the Nantucket Shelf Region in Part II of this report.

Part II of this report describes existing marine protection and management approaches, and describes criteria for evaluating whether a given marine area should be protected or not. Part II is meant to foster discussion of the values of this region and whether this area or portions of it should be protected or managed.

2. HOW THIS STUDY WAS DONE

A key goal of this review is to provide an accurate, objective summary of information concerning the Nantucket Shelf Region. This review therefore utilizes only published, peer-reviewed scientific sources of information (i.e., scientific articles, books, reports, maps, abstracts, and scientific and technical studies or reports produced by or for government agencies). On occasion, books dealing with a specific topic from a layman's point of view, such as nature guides or an in-depth essay or study of a topic, are used. Maps, figures, and diagrams from the original sources are included; very few diagrams were created specifically for this review. This was done to provide transparency and to demonstrate the original source of the information.

In this review, emphasis was put on identifying largescale processes and features of the region. Thus, the review is not intended to be a comprehensive and in-depth review of all the features of this region.

Significant scientific data gaps are identified. Whenever possible, their significance is evaluated according to best professional opinion and existing available scientific or technical literature. If hypotheses, conjectures, speculations, or questions are posed, they are clearly identified and are based on similar processes or phenomena documented elsewhere, and best professional opinion.

The report begins by briefly describing distinct geographic areas in the Nantucket Shelf Region, and then proceeds to describe major physical and ecological features of the region. The second part of the report evaluates marine protection criteria and models.

Fishing boat on Nantucket Sound. photo: NOAA library

3. GEOGRAPHIC AREA OF THIS REVIEW

In this review, the broad shallow shelf area covered by Nantucket Sound, Nantucket Shoals, the Great South Channel and the area south of Martha's Vineyard is called the Nantucket Shelf Region. The goal of this review is to identify largescale physical and ecological processes characteristic of the Nantucket Shelf Region. Information concerning such regional processes covers a wide geographic area that includes the entire shelf region east and south of Cape Cod, extending to the edge of the continental shelf between 100 meters and 200 meters depth. The review draws upon information concerning Nantucket Sound, Nantucket Shoals, the Great South Channel, Vineyard Sound, Georges Bank, the nameless area of continental shelf south of Martha's Vineyard, and the continental shelf area encompassing these geographic regions.

Each of these geographic areas is briefly described below.

Nantucket Sound is defined as the roughly triangular area of continental shelf that lies between the southern shore of Cape Cod (between Monomoy and Mashpee), and the islands of Martha's Vineyard and Nantucket (Figure 1). Nantucket Sound constitutes a small, shallow marine basin whose edges are formed by the islands of Nantucket, Martha's Vineyard and Monomoy, the submerged shoals associated with these islands, and by the Cape (U.S. Department of Commerce, Coast and Geodetic Survey Chart No. 1209, 1970). At its western end, Nantucket Sound merges with Vineyard Sound.

Nantucket Shoals is a broad area of shallow sandy shelf that extends south, southeast and east of the island of Nantucket. The area has a complex, dunelike topography that reflects the strong tidal currents. On the crest of the shoals and in the troughs between them are small linear sand waves that are largely at right angles to the dune crests, although some of the larger sand waves on the crest of the shoals parallel the current. In this area, the shoals consist of reworked glacial sediments that have been deposited over a silt bed of unknown thickness containing Eocene plant spores and pollen (Uchupi and Austin, 1987). Phelps Bank, nearly 50 miles southeast of Nantucket, represents the most seaward extent of the Shoals, with water depths of 40 to 60 meters. Nantucket Shoals is truncated by the Great South Channel to its east and southeast.

The Great South Channel is a submarine valley that runs in a north-south direction, out of the Gulf of Maine, cutting its way between the hilly mass of Georges Bank on the east and the high sandy plateau of Nantucket Shoals on the west. At its shallowest, the channel formed by this underwater valley is about 50 meters deep. The valley links Wilkinson Basin in the southern Gulf of Maine, where water depth exceeds 150 meters, with the continental shelf southeast of Nantucket Shoals. The terminus of the Great South Channel is on the outer shelf near Hydrographer Canyon (Uchupi, 1965).

Ships approaching or leaving the Gulf of Maine or Massachusetts Bay use the Great South Channel to skirt the treacherous shallows of Nantucket Shoals and Georges Bank. The Great South Channel is also one of the major spring feeding grounds for the western North Atlantic population of a critically endangered species of whale, the Right Whale (*Eubalaena glacialis*). The Right Whale congregates by the dozen in this area, because their favorite food source, a copepod, typically undergoes a spring population explosion in this area. The South Channel Ocean Productivity Experiment, or SCOPEX, was designed to evaluate the productivity in this area (Kenney and Wishner,1994).

South of Martha's Vineyard, there is a broad expanse of shelf that is characterized by the lack of shallow offshore shoals. This southern New England shelf area slopes down gradually to the edge of the continental shelf above Atlantis Canyon, at a depth of about 120 meters. Here, the gradient steepens, dropping 300 meters in a distance of a little over 50 kilometers, to the continental slope below (Uchupi, 1965).

Georges Bank is a shallow elongate bank on the continental shelf east of New England (Figure 1), with water depths ranging from 3 to 150 meters. The area covered by Georges Bank is roughly 40,000 kilometers squared (km^2). It is bordered on the north by the deeper waters of the Gulf of Maine, while the Atlantic Ocean forms the southern margin (Valentine and Lough, 1991). Tidal currents flow dominantly northwest and southeast. Georges Bank is eroding since no new sediment is reaching it from the continent. Sand is winnowed from Georges Bank by strong tidal and storm currents, leaving behind gravel "pavement" in the northeastern area, and coarse sand-gravel in the middle portion (Valentine and Lough, 1991). Sand ridges 20 to 30 meters high exist on the crest of the bank in the northeastern area, formed by rapid currents, much as strong winds deposit sand dunes if enough sand is present (Twichell et al., 1987).

The water over Georges Bank is well-mixed due to the strong currents and waves, and form a distinct water body separated by oceanographic fronts from the stratified water of the Gulf of Maine and the Atlantic Ocean. These different water masses have different temperatures, salinity, nutrient concentrations, and differ in their capacity to support phytoplankton and zooplankton and the animals that feed upon these (Valentine and Lough, 1991).

Georges Bank was once a rich fishery due to its shallow, well-mixed, highly productive waters, but the fisheries are now depleted due to overfishing. By the late 1980's, many Georges Bank fishery populations such as cod, haddock, herring, and scallops had declined, while others such as skate and dogfish populations had expanded rapidly (NOAA, 1991, in Valentine and Lough, 1991).

Between Georges Bank and the New York Bight, there are 10 major submarine canyons leading from the shelf into the slope environment. These are, going from north to south: Corsair Canyon, Lydonia Canyon, Gilbert Canyon, Oceanographer Canyon, Welker Canyon, Hydrographer Canyon, Veatch Canyon, Atlantis Canyon, Block Canyon, and Hudson Canyon (Uchupi, 1965; Shepard and Dill, 1966; reviewed in Pratt, 1973).

Typically these submarine canyons are relatively straight canyons with a V-shaped profile reflecting their origin as stream-cut valleys, with sloping walls that may be as steep as 30 degrees in places. Sedimentary rock and semi-consolidated sediments are frequently exposed on the canyon walls, creating a terraced pattern (Pratt, 1973).

Submarine canyons are widely believed to result from stream erosion of the continental shelf during periods of low sea level during glacial periods (Ross, 1968). At its lowest, sea level would have been about 300 meters lower than today's sea level, exposing the continental shelf to the air and to terrestrial erosion processes (Emery, 1987).

Silts are the predominant sediment in the floors of these downward-sloping canyons, carried there by intermittent strong currents flowing down the shelf and into the heads of the canyons (Pratt, 1973; Butman, 1988). At the bases of the canyons, on the continental slope at depths of over 2000 meters, there are depositional fans, or deltas, of fine-grained silts. Currents flowing down the canyons were documented by early studies (Trumbull and McCamis, 1967; Ross, 1968; and Dillon and Zimmerman, 1970) and by later studies (Butman, 1988).

4. GEOLOGY

The Nantucket Shelf Region has been submerged by the sea and reemerged as dry land many times. This area was a continental shelf for many millions of years prior to the onset of glaciation in the Pleistocene. Before the Pleistocene, parts of the shallow continental shelf were above sea level and consisted of a coastal zone of plains and low hills that gradually became lower toward the east, where an ancient shoreline stood (Strahler, 1966). See Figure 2 for a geological time scale (Raup and Stanley, 1978).

The landforms that we call Cape Cod, Nantucket, and Martha's Vineyard did not come into being until very recently, during the last or Wisconsin stage of glaciation which began some 50,000 to 70,000 years ago (Strahler, 1966). These modern landforms result from the deposition of boulders, cobbles, gravel and sand as terminal moraines and ice-contact deposits formed as the glaciers were receding. Below this veneer of glacially-deposited sand, gravel and boulders lies a series of ancient landscapes, stacked like the layers of a cake.

Shoals off Nantucket. photo: MASSGIS

The information concerning these ancient, pre-Pleistocene landscapes comes from seismic reflection profiling studies of the sediments and rocks underlying Nantucket Sound and nearby regions, performed in the 1970's and 1980's (O'Hara, et al., 1976; O'Hara and Oldale, 1980; O'Hara and Oldale, 1987). The seismic reflection profiling studies by O'Hara and Oldale were conducted in order to assess sand and gravel resources, evaluate the environmental impacts of offshore mining of sand and gravel and of offshore disposal of solid waste and dredged materials, to identify and map offshore geology and to determine the geologic history of this area of the shelf. These seismic reflection studies provide a significant portion of the total scientific knowledge that we have concerning Nantucket Sound.

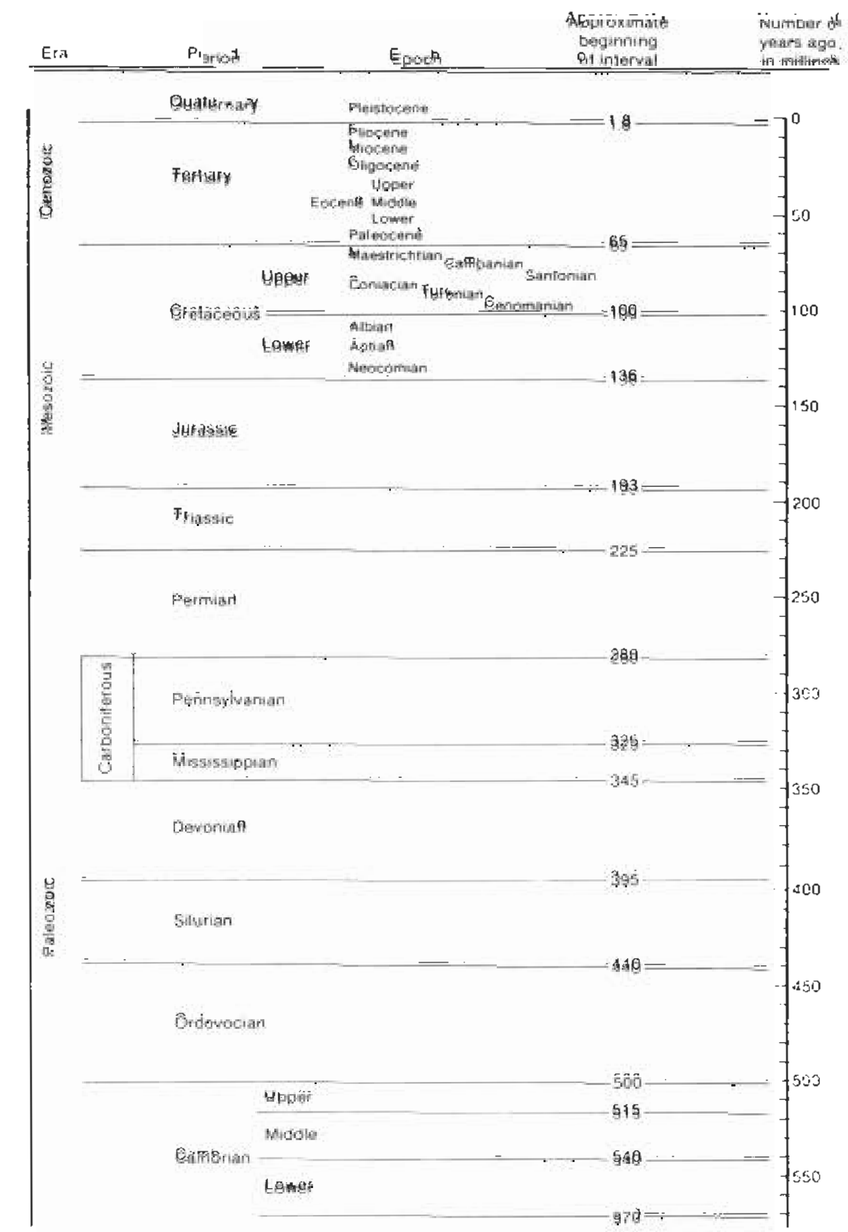


Figure 2. Geological Time Scale. From Raup and Stanley (1978)

4.1. Pre-Cretaceous Landscape

Beneath Nantucket Sound, the oldest, deepest rocks are believed to be of Mesozoic age or older, formed before the Cretaceous Period. The bedrock is crystalline basement rock that represents the North American continental plate. Sedimentary rock is deposited on top of the crystalline basement. During the Mesozoic Era, as the North American continental plate moved apart from the European and North African continental plates, the Atlantic Ocean widened, in a tectonic process called rifting. The sedimentary rocks formed from sediments deposited in a shallow sea that covered the continental shelf, which were later consolidated into solid rock by metamorphic processes (Oldale et al., 1973).

The Mesozoic landscape sloped gently towards the south, and was cut by streams and rivers that flowed south and southeast towards the opening Atlantic Ocean. These rivers flowed down from the North American continental highlands.

4.2. Late Cretaceous and Early Tertiary Coastal Plain

During the last part of the Mesozoic (Late Cretaceous) and continuing into the early Tertiary, coastal sediments were deposited in a thick layer on the bedrock shelf, thickening towards the ocean. These coastal plain sediments included both consolidated and unconsolidated sands and silty clays containing some gravel (Oldale et al., 1973). The coarse grain size of these sediments suggests that they were deposited underwater in a nearshore shallow environment, perhaps much like offshore conditions today.

In Nantucket Sound, there is an unconformity between portions of the Pre-Cretaceous bedrock and later Late Cretaceous-Tertiary sediments, indicating that portions of the ancient bedrock were exposed to erosion. The eroded fragments of pre-Cretaceous crystalline rock ended up as part of the Late Cretaceous coastal plain deposits.

4.3. Late Tertiary and Pleistocene River Valleys

During the late Tertiary and early Pleistocene, the area of Nantucket Sound was filled by coastal plain sediments. A major unconformity shows that this landscape underwent massive erosion. The erosion of this landscape is perhaps best seen in an extensive erosional scarp, or eroded cliff, that faced north, which is now buried beneath the more recent glacial sediments of Nantucket Sound. This buried eroded cliff runs east-west and extends from eastern Georges Bank to western Long Island Sound. Evidently, the area south of this scarp was a highland or range of hills that eroded. The streams and rivers that flowed north into the valley representing the proto-Nantucket Sound had their headwaters in this range of coastal hills that ran from west to east for hundreds of miles, parallel to the Atlantic coast. (O'Hara and Oldale, (1987).

Similarly, the plains to the north of the proto-Nantucket Sound valley were eroded by numerous streams and rivers that flowed south (Figure 3) and then out of the east to the Sound, towards the area of the present-day Great South Channel. These streams cut long, linear southwest- trending valleys that flowed towards the center of Nantucket Sound. Some of these streams, in the northern part of Nantucket Sound, may have cut down to the underlying pre-Cretaceous bedrock, exposing that ancient rock.

Drainage from the proto-Nantucket Sound was towards the east. The east-flowing river (outside the area in Figure 3 mapped by O'Hara and Oldale) broke through the line of hills at a water gap and then flowed south across the exposed continental shelf to the Atlantic Ocean. The Great South Channel may have been the water gap that allowed drainage of the Nantucket Sound area towards the sea (O'Hara and Oldale, 1987). The Great South Channel may also have drained the western Gulf of Maine (Oldale et al., 1973). Today, the Great South Channel still connects the southern Gulf of Maine with the North Atlantic, but the Late Tertiary watersheds that drained into it and the low line of hills which it breached are now buried beneath Pleistocene glacial sediments of Nantucket Sound and Cape Cod and flooded by the rising sea.

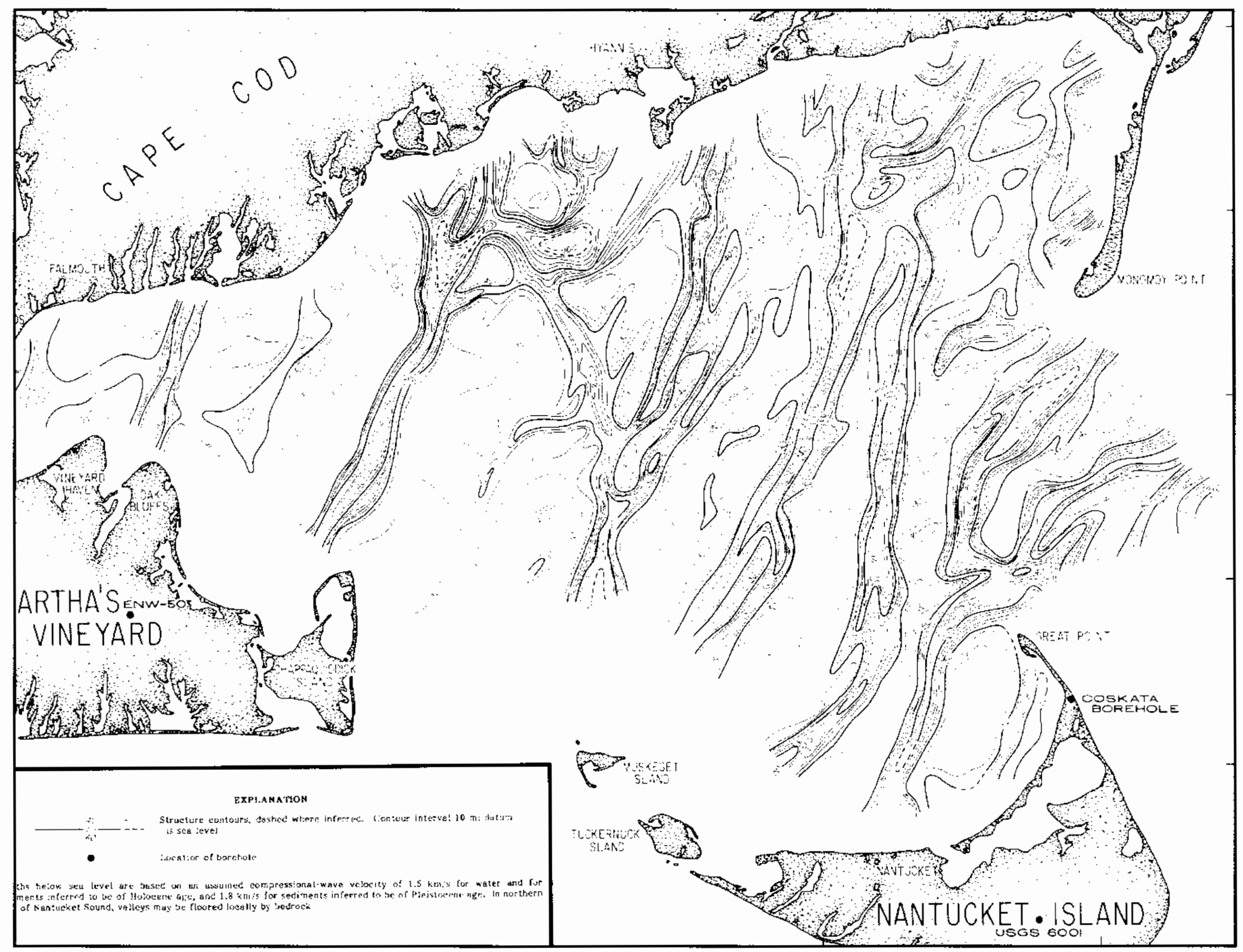


Figure 3. Depth to Submerged Coastal Plain Rocks. O'Hara and Oldale (1987).

4.4. Pleistocene Glaciation and the Formation of Cape Cod and the Islands

The continental glaciers that formed present-day Cape Cod and the Islands were but small outliers of the great Laurentide Ice Sheet, the massive glacier that covered northern North America during the Pleistocene. This massive ice sheet, 10,000 feet thick or more at its greatest, flowed out from its center at Labrador towards the continental shelf. In eastern North America, the ice mainly flowed south and east.

The direction of flow of the Pleistocene glaciers that crept down from the north was probably influenced by the preexisting linear valleys cut by the south- and north-flowing streams during Late Tertiary times. Like grooved pavement, the valleys probably acted to entrain the glacial ice, which would have settled deep into the valleys (O'Hara, 1981b). The Late Tertiary linear valleys may have helped to determine the shape of the Nantucket Shelf region by influencing the direction of flow of the Pleistocene glaciers.

The landforms of Cape Cod, Nantucket, Martha's Vineyard, Nantucket Shoals, the Great South Channel, and much of Georges Bank were formed by glacial processes in the last Ice Age, the Wisconsin stage. Nantucket and Martha's Vineyard were formed by the bulldozer action of glaciers pushing sediments ahead as the Laurentide Ice Sheet flowed south from New England and Canada.

Such sediments deposited in front of a glacier are called terminal moraines. A terminal moraine also receives the sediments that are carried by the ice and deposited as the glacier melts at its terminus. A terminal moraine typically reflects the shape of the end, or terminus, of the glacier that molded it. When the glacier retreats, it leaves behind the terminal moraine.

The terminal moraines that form the high spines of Nantucket and Martha's Vineyard were formed by distinct lobes of glacial ice. The Nantucket Sound lobe marked the farthest advance of glacial ice in the Nantucket Shelf region (Figure 4, from Strahler, 1966). Long Island and Block Island were also formed at the same time and in the same manner (Strahler, 1966). Cape Cod was not yet formed. Nantucket and Martha's Vineyard are therefore older than the Elizabeth Islands and the Buzzards Bay and Sandwich Moraines, which were deposited later, during the second stillstand of ice (Strahler, 1966).

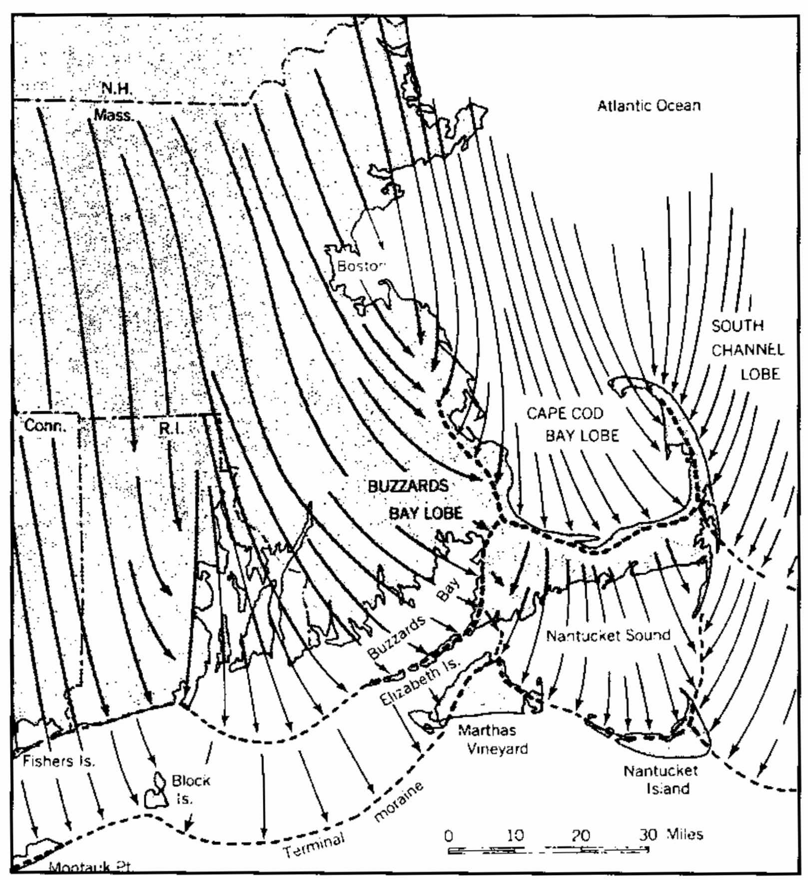


Figure 4. This map of southeastern New England shows by arrows the directions of flow of ice of the Wisconsin Stage as well as the two positions of ice standstill (dashed lines). (Based on a map in Woodworth and Wigglesworth's Geography and Geology of the Region Including Cape Cod, 1934). From Strahler (1966).

About 18,000 years BP, the glaciers began melting and retreated northward, and then halted. This second ice margin position, or stillstand, was held for several thousand years. Now the ice margin of the Cape Cod Bay lobe and the Buzzards Bay lobe ran through a line defined by the recessional moraines of the Elizabeth Islands and Cape Cod, in particular the Buzzards Bay Moraine and the Sandwich Moraine, which were deposited then. Meltwater streams eroded the moraines and washed sediment down to form the broad, gently sloping glacial outwash plains that form most of the southern and eastern portions of Cape Cod. A glacial lake formed in Nantucket Sound at the melting edge of the retreating ice sheet (Gutierrez et al., 2003).

In Nantucket Sound, glacial drift sediments were deposited in the narrow linear valleys that existed before the Pleistocene glaciation. Thicknesses of these Pleistocene glacial drift sediments reach over 100 meters in some of the deeper valleys, and thin to 10 meters or so in areas that were high (see Figure 5, O'Hara and Oldale 1987).. The current bathymetry of Nantucket Sound (see Figure 6, from O'Hara and Oldale, 1987) reflects a combination of glacial and post-glacial sediment deposition processes.

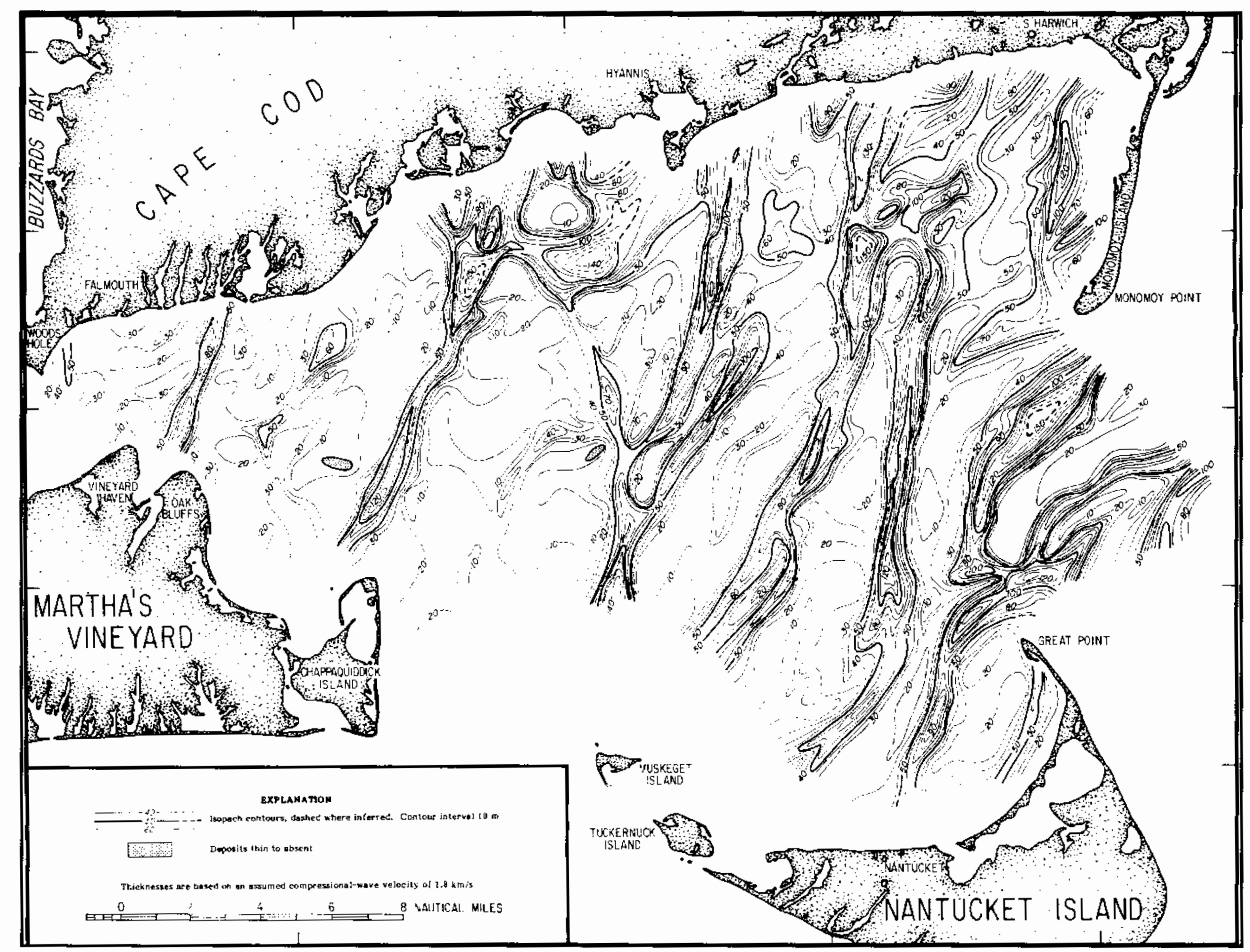


Figure 5. Thickness of Glacial Drift Deposits. O'Hara and Oldale (1987).

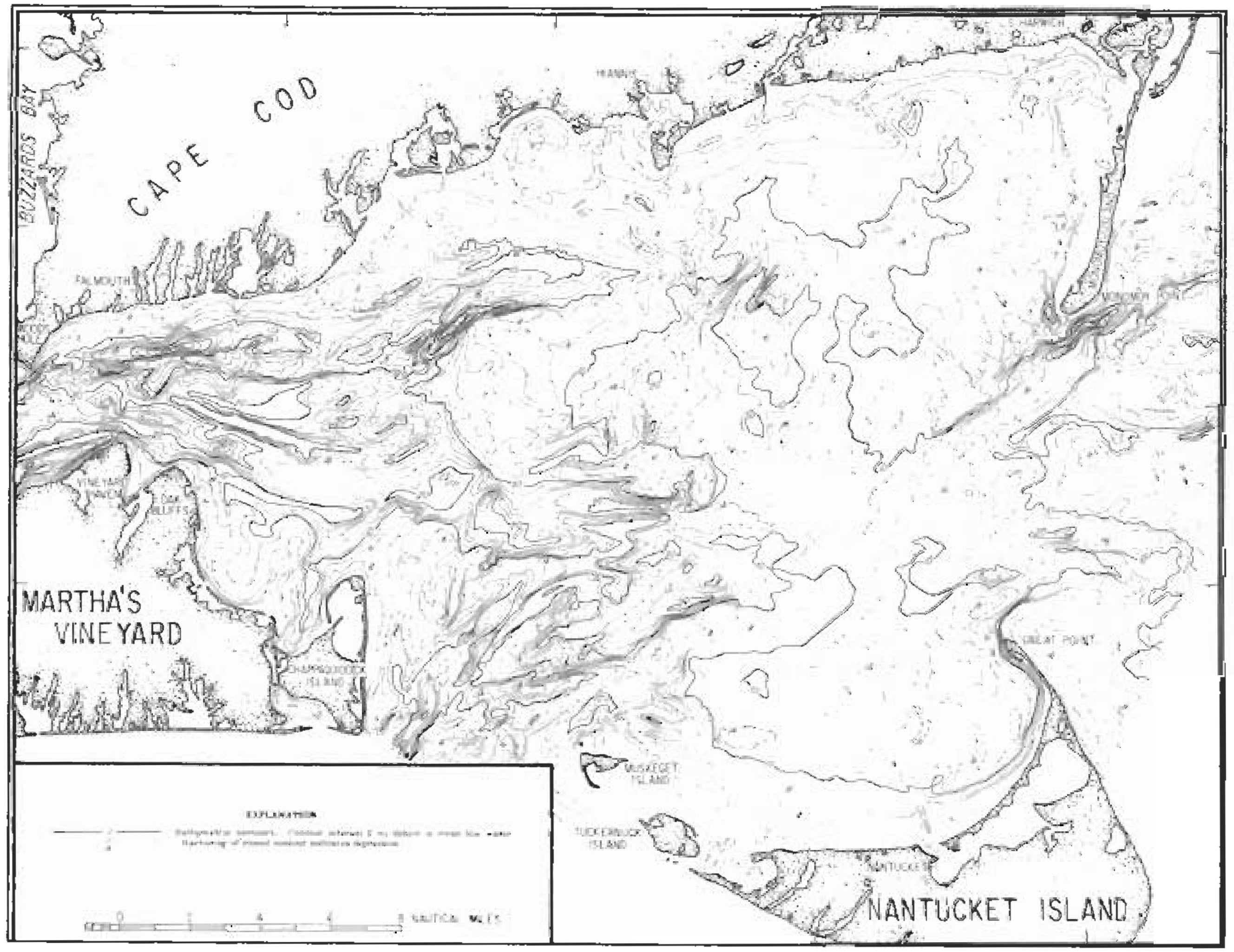


Figure 6. Existibg Sea Floor Topography. O'Hara and Oldale (1987).

The area of the Great South Channel, which may have been a Tertiary water gap in an east-west line of coastal hills (O'Hara and Oldale, 1987), was covered by a different glacial lobe, the Great South Channel Lobe (Strahler, 1966). The intersection between the South Channel Lobe and the Nantucket Sound ice lobe coincides with the eastern edge of Nantucket Sound. Today, water depths are still shallow at the eastern edge of Nantucket Sound, because of the ridge of glacial sediments deposited in the gap between the Great South Channel ice lobe and the Nantucket Sound ice lobe (Figure 6, from O'Hara and Oldale, 1987).

4.5. Relative Sea Level Rise

During glacial times, sea level was nearly 300 to 500 feet (100 to 160 meters) lower than today's levels, because of the huge amount of seawater locked up in glacial ice. The Nantucket Shelf region was exposed land (Figure 7, from Emery, 1987). The shoreline was much closer to the edge of the continental shelf than its present position, which today is near the 200-meter depth contour (Uchupi, 1965). During a glacial period of low sealevel, water depths would have quickly deepened to hundreds of meters a short distance offshore.

During this period of exposure to sun, wind and rain, the continental shelf received precipitation, underwent weathering and erosion, and drained towards the sea, (Strahler, 1966). Fresh groundwater accumulated in the subsurface of the exposed Nantucket Shelf region (Kohout et al., 1977). Streams and rivers cut down through the exposed sediments of the continental shelf, heading for the edge of the continental shelf only miles away. The submarine canyons, such as Oceanographer Canyon, that plunge off the edge of the continental shelf were probably formed during this lowstand, carved out by the great glacial rivers that entered the sea closer to the edge of the continental shelf.

What animals and plants lived here? The animals and plants and habitats of this coastal glacial ecosystem probably would have resembled a present-day Arctic coastal ecosystem, but there is scant information from the Nantucket Shelf region from this brief emergent period. Mastodon teeth and bones have been recovered (Emery).

About 12,000 years ago, rapid global warming caused the glaciers to shrink rapidly and sea level to rise (Strahler, 1966). The rapid warming event caused a rapid retreat of the glaciers, and meltwater streams eroded and carried sediment out to form glacial outwash plains. Nantucket Sound remained a lake until about 9,500 years BP, when sea level was 30 meters below its present level (Uchupi et al., 1996). Beginning about 7,600 years BP, rising sea level drowned the lake and the shoreline migrated inland as the sea inundated the coastal valleys and plains (Gutierrez et al., 2003). By about 1,000 years BP, sea level reached its approximate present level. Since then, sea level continues to rise at the rate of approximately one foot per century over the past century, and it is expected to rise at least 19 inches over the next century (IPCC, 2002).

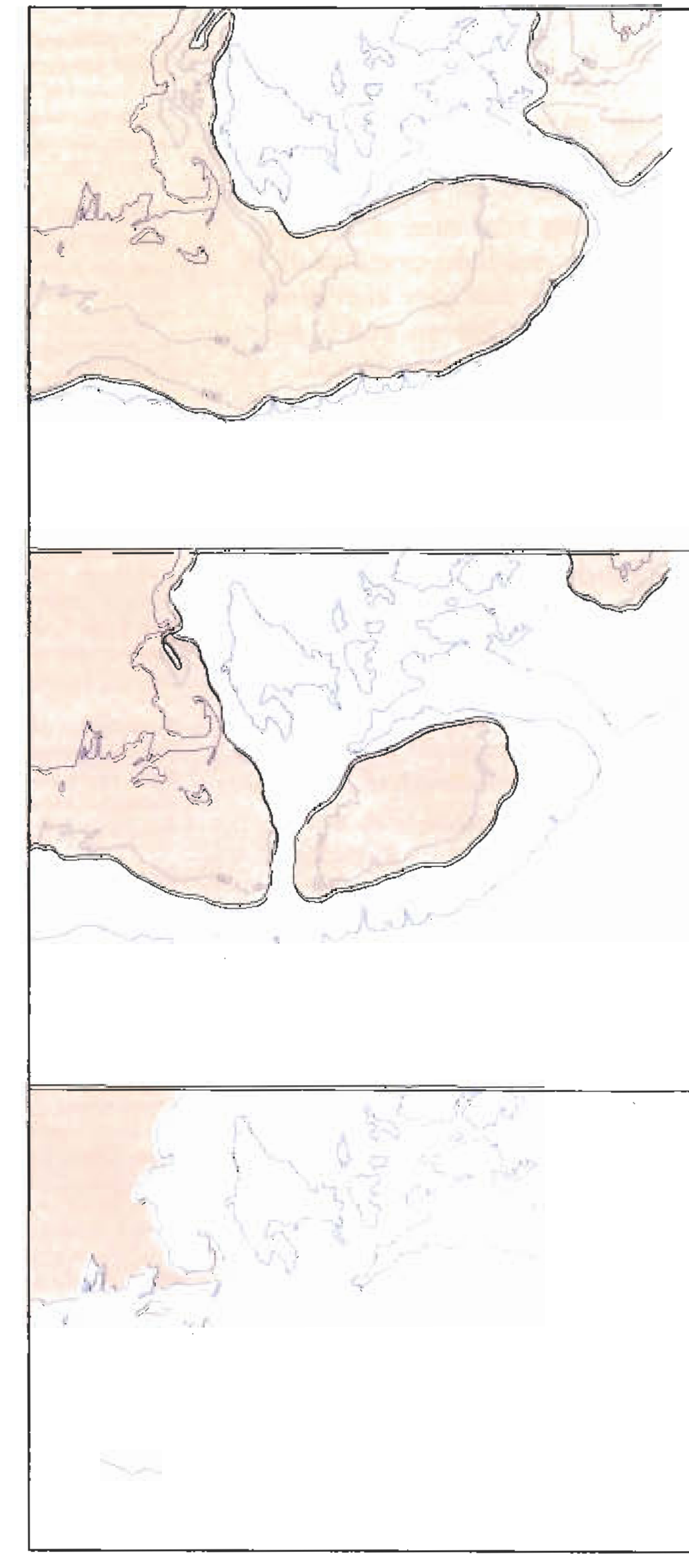


Figure 7. Georges Bank during the past 16,000 years (BP = Before Present): (top) Georges Cape (14,000 years BP), (middle) Georges Island (11,500 years BP), and (bottom) Georges Bank (present) formed as sea level rose at the end of the Pleistocene epoch. Emery (1987).

4.6. Sedimentary Environments

Sediments in the Nantucket Shelf Region are of the type that geologists call clastic, that is, formed by the disintegration of rock into small particles. Water, waves, wind, erosion, abrasion, temperature extremes and the weathering action of soil microorganisms break down rock into sediment particles. These sediments are then carried into the sea by rivers and streams. Clastic sediments have been deposited in this area of the continental shelf for many millions of years, beginning in the late Cretaceous.

New England and areas to the north do not have massive coral reefs or reefs built up of other limestone-forming invertebrates. Biogenic sediments, or sediments that are deposited by algae, reef-forming corals and other invertebrates that secrete limestone, are uncommon in this region. Unfortunately for coral reef-lovers, the cool temperate waters are not favorable for growth of carbonate-secreting, reef-forming animals, since the minerals they secrete are not stable for long due to the cool temperatures, which tend to dissolve carbonate.

Other biogenic sediments, such as opal-like silica, are deposited by diatoms, a type of microscopic algae. Diatoms are common in offshore waters and in the Gulf of Maine, and can form spring and summer blooms. There is, however, no information on biogenic silica production in the Nantucket Shelf Region.

Clastic sediments can have many different compositions reflecting the parent rock. The more resistant and long-lived sediment grains consist of the harder rocks and minerals such as quartz, rutile, ilmenite, garnet, and other tough igneous and metamorphic minerals derived from the weathering of granite, gneiss, diorite, and basalt. Such sediment grains of more resistant minerals tend to weather more slowly to form gravel, sand, silt and clay. Softer sediment grains of feldspar, soapstone, schist, and other soft minerals and rocks tend to weather more quickly into fine-grained clays. Limestone (carbonate) and basalt can also weather to form gravel, sand, silt and clay.

The clastic sediments of the continental shelf of New England reflect the nearby parent rocks and sediments, namely, the pre-Cretaceous igneous and metamorphic bedrock of the North American continent, younger sedimentary rocks and sediments from the Tertiary period, and even more recent Pleistocene glacial drift carried from many areas of the Northeast. Although one may find pebbles or cobbles of limestone or basalt, extensive sand deposits composed of limestone or basalt are not common in New England because massive limestones and basalt are not common rocks in New England.

Sediment grain size is an important attribute in the marine environment. The size of a sediment grain may seem irrelevant to us. However, to a tiny invertebrate living on or beneath the sediments or a fish laying eggs on the bottom, sediment grain size is a critically important feature. Fish feed upon the many invertebrates that live in and on the sediments. Some invertebrates prefer to live in or on muds, while others prefer sand. Certain fish and shellfish prefer gravels and sands to muds, silts or clays.

Sediment grain size depends on the type of parent rock, the length of time the sediment grain has been weathering, how far the sediment grain has been carried by water or wind (relating to abrasion time), and the wave and current energy in an area. Bigger waves and faster currents with more energy can move larger sediment grains than smaller waves or slower currents. A fast current can winnow out the fine silts and clays and sands, leaving behind coarser gravels, pebbles and cobbles. Currents that slow down deposit their sediment loads because they no longer have enough energy to keep moving sediment grains.

4.7. Benthic Habitat Mapping

National Marine Sanctuaries are marine and coastal areas of special biological significance. The National Marine Sanctuary System, administered by NOAA, requires seabed and habitat maps to serve as a basis for managing sanctuary resources and for conducting research. Also, since the decline of the Northeast fisheries, the need to understand, identify and protect essential fish habitat has become critical.

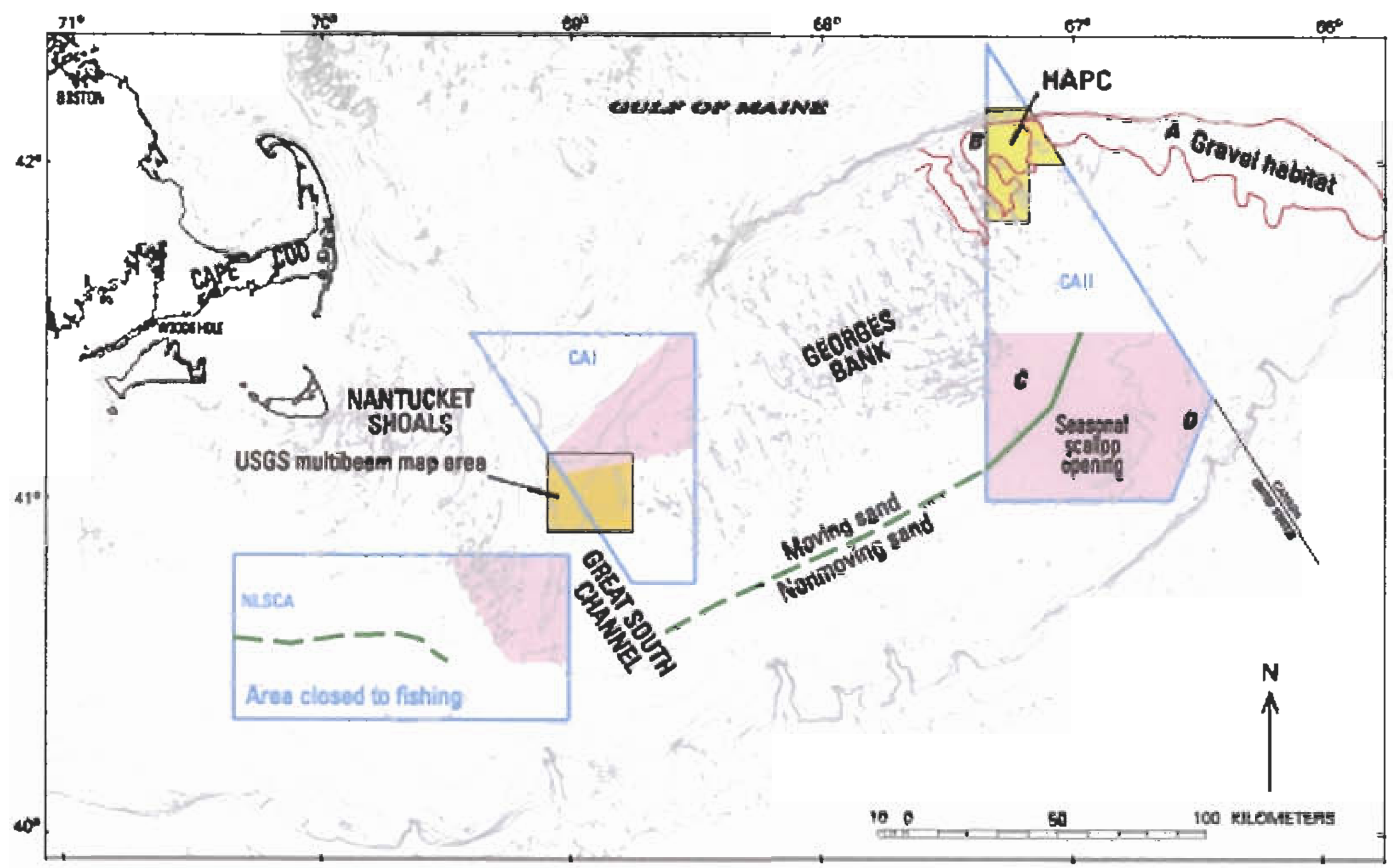


Figure 8. Benthic habitat mapping of Georges Bank, using multisensor approach. From USGS Fact Sheet FS-061-01.

As a result, geologists and biologists of the U.S. Geological Survey, the National Marine Fisheries Service and National Marine Sanctuaries System of NOAA, and universities have conducted detailed studies of the physical and biological characteristics of benthic habitats in a number of National Marine Sanctuaries and important fishing grounds. These marine habitat geology and fish ecology studies were conducted to study the interplay of geologic factors and biological habitat needs of species, and to better understand how physical habitat influences the survival and success of important fish and shellfish species (Valentine et al., 2001; Valentine and Lough, 1991; Lough et al., 1989; Collie et al., 1997; Auster et al., 2003; USGS Fact Sheet 078-98, May 1998; USGS Fact Sheet FS-142-00, December 2000; USGS Fact Sheet FS-061-01, July 2001).

Using multibeam bathymetry and sidescan sonar, underwater video, underwater photography, and sediment sampling at thousands of stations, marine scientists are mapping underwater topography, sedimentary bedforms (sand dunes, sand waves, ripples, channels), sediment grain size, benthic fauna, and the behavior of fish and invertebrates, the effects of habitat disturbance by storms, fishing gear and moving sand, and habitat preferences among different fish and invertebrate species. The multisensor mapping approach can document habitat characteristics at many size scales, ranging from several to many square miles (megahabitat), hundreds to tens of meters (local habitat), and several meters down to several centimeters (microhabitat).

Seabed mapping surveys have been carried out in Stellwagen Bank National Marine Sanctuary (NMS), and Georger Bank to define and map biological habitats, assess natural and human disturbance of habitats, and identify areas where contaminants might accumulate (Valentine, Cochrane and Scanlon, MTS Journal, Vol. 37, No. 1, p. 10-17).

In Georges Bank, several years of such studies show that: (USGS Fact Sheet FS-061-01; Valentine and Lough, 1991)

- Herring spawning sites are located on gravel bottom only where currents are strongest;
- Juvenile cod survive best on gravel habitat, especially where sponges, tube worms, and other attached species (epifauna) increase the complexity of the seabed, possibly because predation is reduced (juvenile cod are less visible against gravel bottoms and where there are other organisms that provide cover);
- Attached species are not able to colonize gravel habitat that is buried occasionally by moving sand, depending on periodicity;

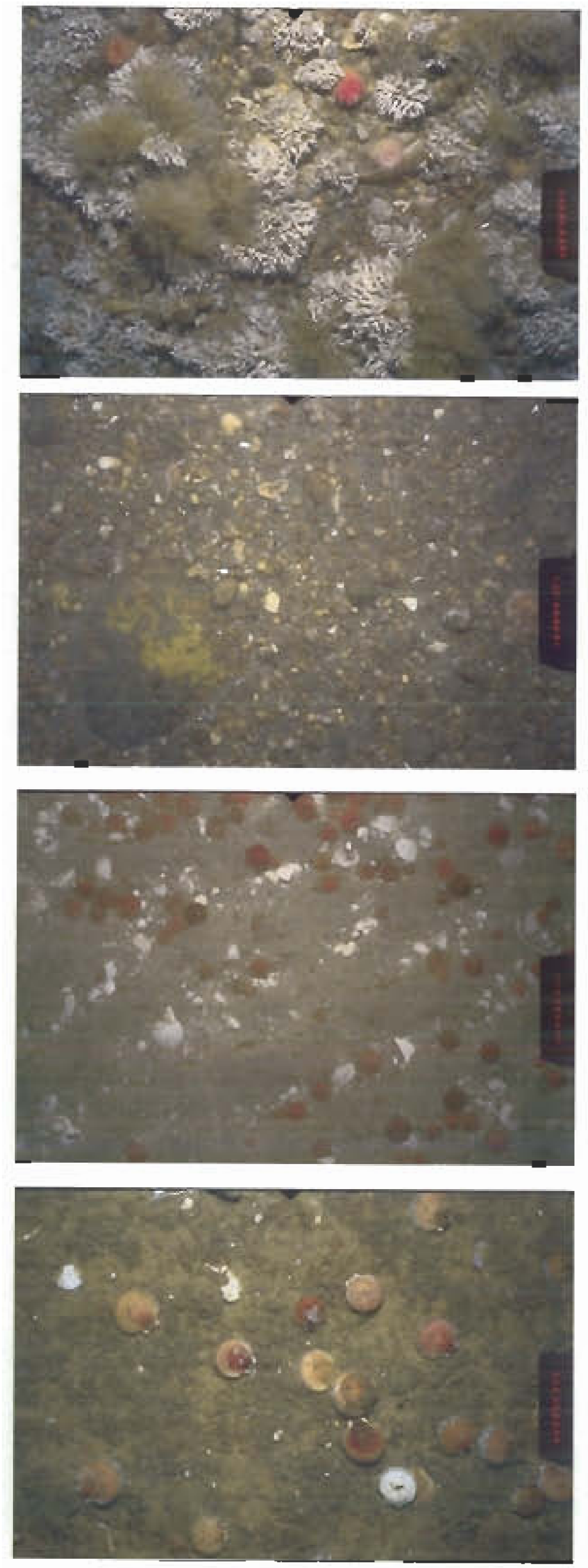


Figure 9. Photographs of the seabed showing some typical Georges Bank habitats. See Figure 10 for locations. A, Undisturbed gravel habitat with epifauna of tube worms and other attached species. B, Gravel habitat disturbed by scallop dredges and lacking epifauna. C, Moving sand habitat (strong bottom currents) with sand dollars in ripple troughs. D, Non-moving sand habitat (weak currents) with sea scallops.
USGS Fact Sheet FS-061-01.

- Dredging and trawling on gravel habitat remove epifauna and decrease habitat complexity, but fishing gear apparently has less long-term impact on sand habitat, especially where sand is moved by bottom currents, depending on periodicity;
- Scallops prefer habitats of gravel and nonmoving sand (weak bottom currents);
- Closure of large areas to fishing allowed depleted sea scallop populations to increase markedly in 4 to 6 years;
- Some sand-dwelling flounder species possibly prefer moving sand (strong bottom currents), but others prefer nonmoving sand habitats.

Figures 8 and 9 show the location of the benthic habitat mapping studies on Georges Bank, and examples of benthic habitat (from USGS Fact Sheet FS-061-01).

In Georges Bank and in Stellwagen Bank National Marine Sanctuary, multisensor studies at several thousand stations have provided information on the different habitats present, including the value of sediment bedforms (i.e., sand waves and ripples, troughs) for fish habitat, species preferences for sediment grain size, damage to benthic habitats from mobile fishing gear, the value of undisturbed seabed as habitat for fish and other organisms, and the beneficial fishery habitat effects of removing disturbances to allow the seabed to recover from impacts (Auster et al., 2003; Auster et al., 2001; Auster et al., 1996; Valentine et al., 2001). Examples of benthic habitats and habitat disturbance are shown in Figures 10, 11, 12 and 13 (from USGS Fact Sheet 1998).

Multisensor methods have proved extremely useful in monitoring the effects of fishing gear on benthic habitats and essential fish habitat. Combined with studies of benthic invertebrates and benthic production, sidescan sonar and benthic imaging have shown that mobile fishing gear (trawlers and dredgers) significantly reduces benthic productivity and biomass of Atlantic sea scallops, sea urchins, and polychaete worms on eastern Georges Bank; when such impacts ceased for several years, benthic productivity increased by factors of 5 to 10 or more (Hermsen et al., 2003). On Stellwagen Bank, similar surveys showed that mobile fishing gear altered the physical habitat by removing sedimentary structures (sand waves, depressions) and by removing benthic organisms that provide structural habitat complexity (e.g., sponges, hydrozoans, bryozoans, amphipod tubes, shell aggregates, holothurians, crabs, etc.). Reduced habitat complexity can result in increased predation on juvenile fish and ultimately reduce recruitment (Auster et al., 1996).

In eastern Georges Bank, large sand waves, analogous to underwater sand dunes, have formed in response to rapid storm and tidal currents with speeds ranging from 10 to 100 centimeters per second. Sand waves usually lie at right angles to the direction of the prevailing current.

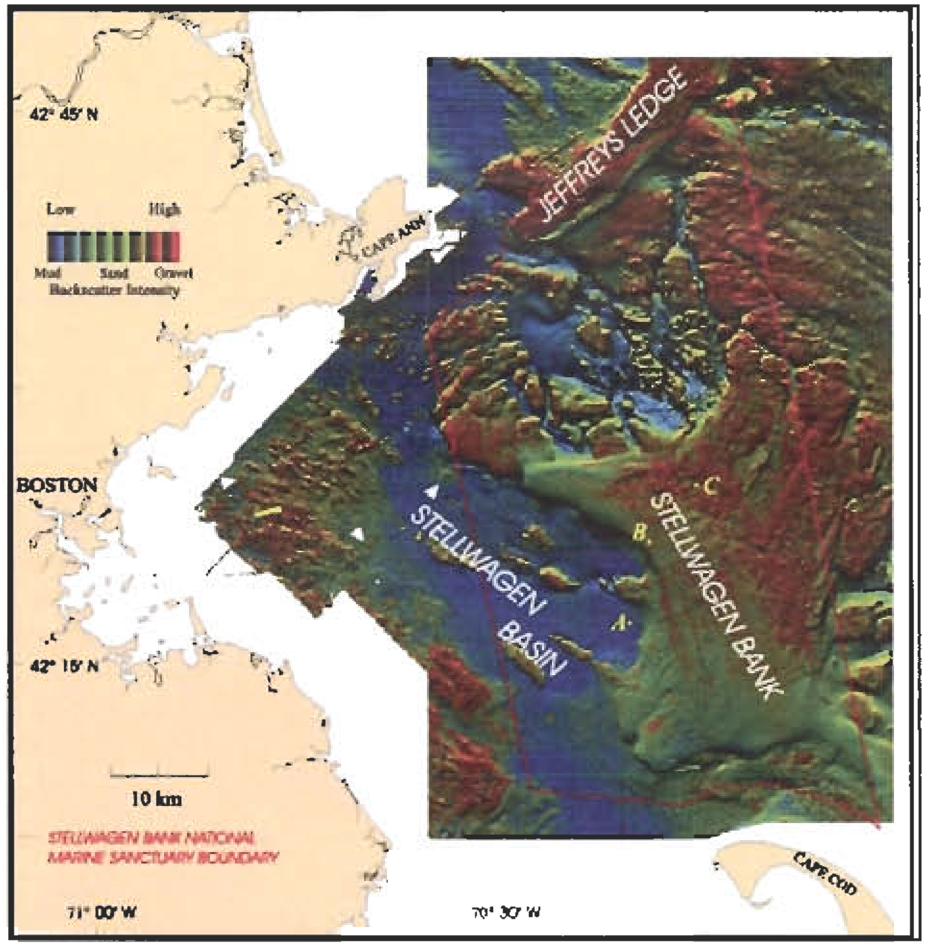


Figure 10. Sun-illuminated map of Stellwagen Bank National Marine Sanctuary and Massachusetts Bay with backscatter intensity draped over the topography. Red indicates high-backscatter material including coarse sand, gravel, and rock; green indicates sand; blue indicates mud. Within each backscatter color interval, the intensity varies from dark to light depending on the sun illumination. The image illustrates the wide variety of sedimentary environments in this region of the coastal ocean. The transitions between sediment types are often very sharp. Topographic features observed here were formed for the most part by glacial processes. Glacial ice containing rock debris moved across the region, sculpting its surface and depositing sediment to form basins, knolls, banks, and other features. Later many of the smaller features were formed during a final period of ice stagnation and melting. Today, the sea floor is mainly modified by storm currents and waves from the northeast. These currents erode sand and mud from the shallow banks and transport them into the basins. Stellwagen Bank and Jeffreys Ledge are shallow banks (20-40 m water depth) covered with sand and gravel. Stellwagen Basin (80-100 m) is floored with mud. In deeper water (85-140 m) in the northeastern part of the image, a fine hummocky pattern on the sea floor was created by gouges (5-10 m deep and up to 120 m wide) caused by icebergs that grounded in the muddy sand at the close of the last period of glaciation. Present and past disposal sites (white arrows) are characterized by high-backscatter material and are especially distinct when the background material is fine grained sediment, such as in Stellwagen Basin. The easternmost arrow points to the presently active Massachusetts Bay Disposal Site. The yellow rectangle in the western part of the map is the location of the new ocean outfall that will discharge treated sewage effluent from the Boston metropolitan area into Massachusetts Bay. USGS Fact Sheet 078-98 (May 1998).

Figure 11. A view of the SEABOSS from below (with base plates removed; see fig. 2). Photograph by Dann Blackwood, USGS. The instruments are as labeled: A, forward-looking video camera; B, lights for forward-looking video camera; C, downward-looking video camera; D, lights for downward-looking video camera; E, 35-millimeter still camera; F, strobe light for still camera; G, modified Van Veen grab sampler; H, depth sensor; I, junction box; J, parallel lasers for scale; K, angled laser for range. From USGS Fact Sheet FS-142-00 (December 2000).

Figure 12. An oblique view of the SEABOSS on deck between stations. Photograph by Dann Blackwood, USGS. From USGS Fact Sheet FS-142-00 (December 2000).

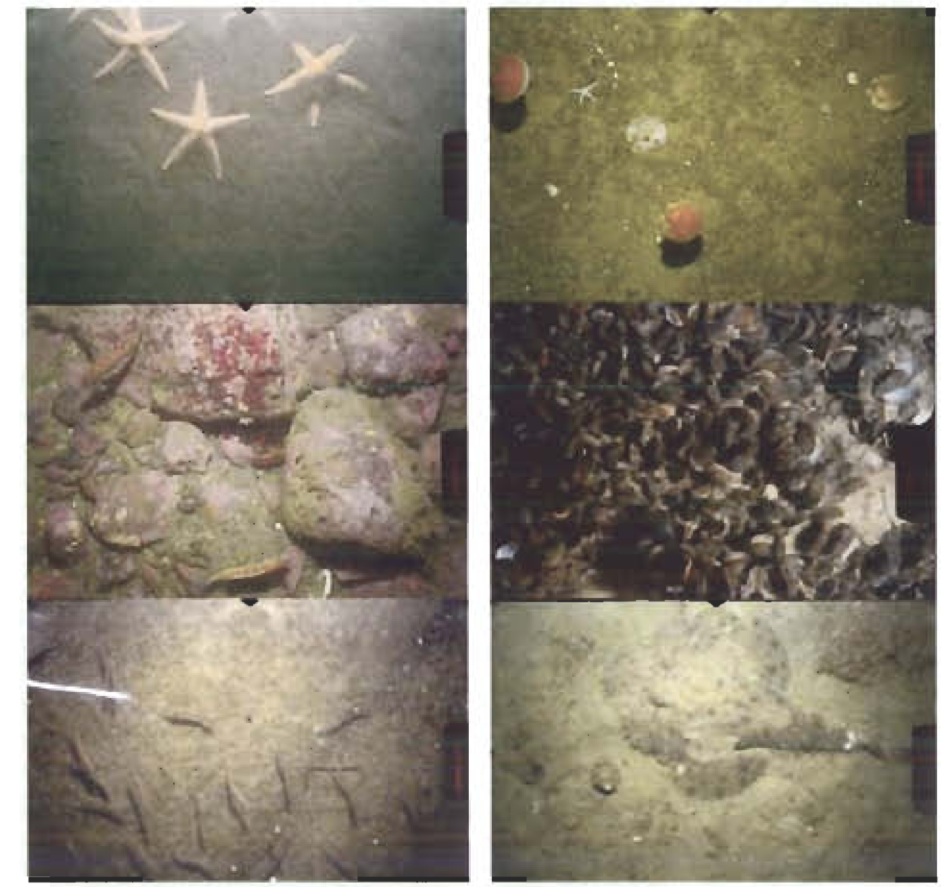


Figure 13. Examples of still photographs taken of different habitats with the SEABOSS during USGS studies. Area shown in each photograph measures about 51 to 76 centimeters. A. Four starfish together on a muddy bottom in the New York Bight. B. Juvenile scallops swimming over a sandy bottom on Georges Bank. C. A boulder mound in western Massachusetts Bay that is providing habitat for lobster and fish. D. Mussels clustered on bedrock in Niantic Bay in Long Island Sound. E. Sand lance schooling over coarse sand in the Stellwagen Bank National Marine Sanctuary. F. A goosefish camouflaged on a muddy sand bottom in the Stellwagen Bank National Marine Sanctuary. From USGS Fact Sheet FS-142-00 (December 2000).

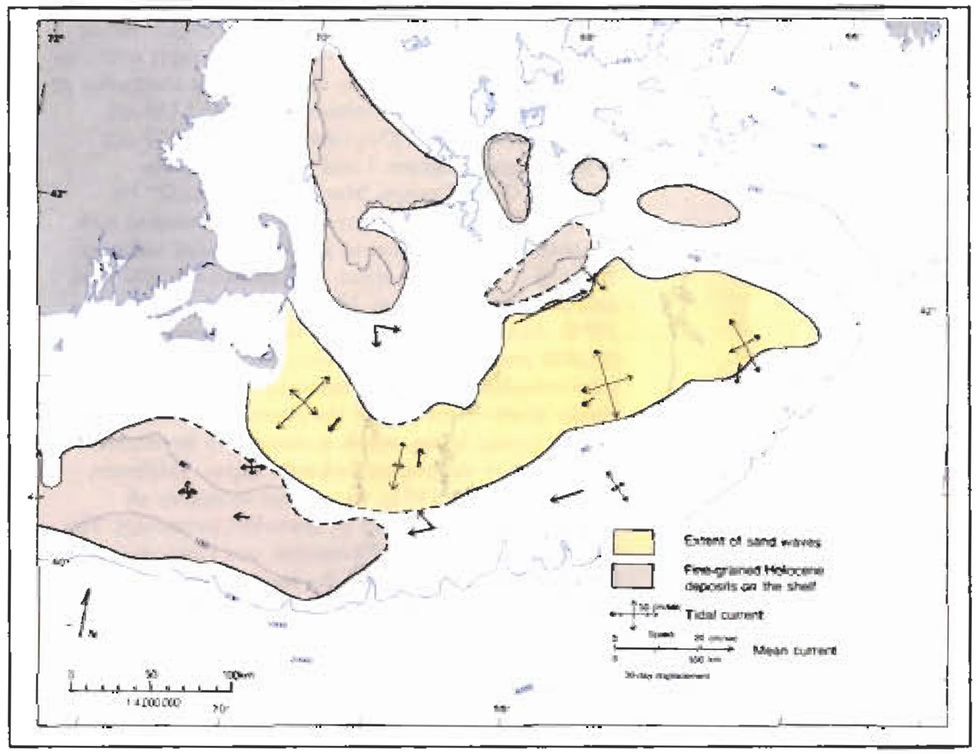


Figure 14a. Summary map showing tidal currents, mean currents, **area** of sand waves, and locations of fine-grained Holocene deposits. From Twichell et al. (1987).

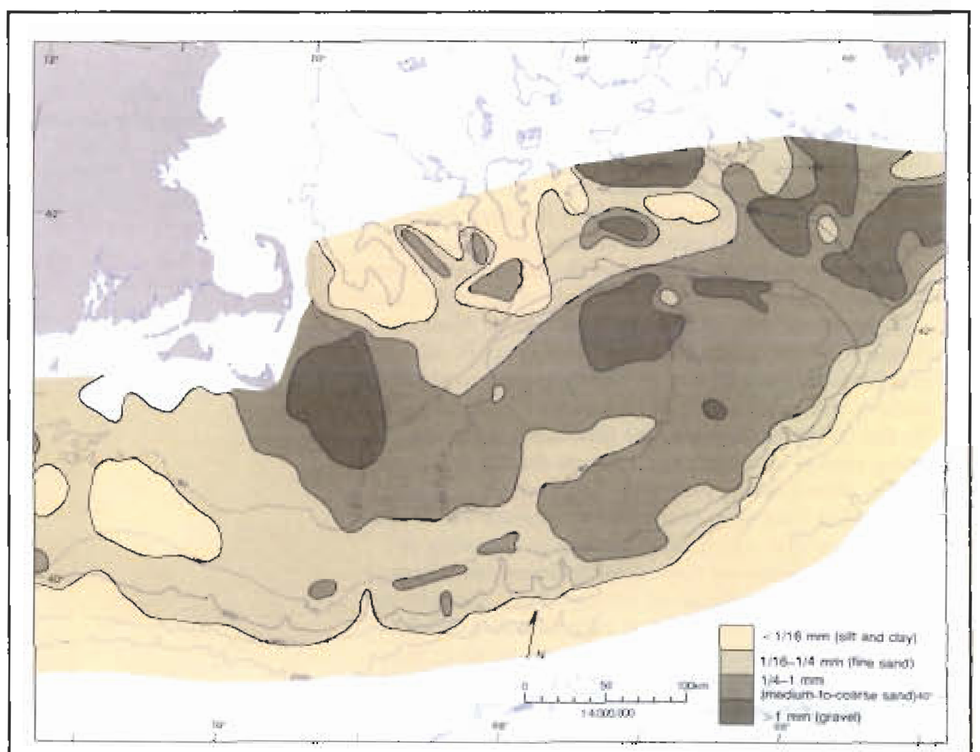


Figure 14b. Median grain size of surface sediments in the Georges Bank area. (Schlee (1973), modified). From Twichell et al. (1987).

They are formed much as desert sand dunes are formed, by a current that carries sand grains forward and then drops the sand grains as the current slows in travelling up the face of the growing dune. The sand waves on Georges Bank reach amplitudes (height from bottom to top of a sand wave) of up to 25 meters (75 feet) with a wavelength of 50 to 300 meters between wave crests, although most are 1 to 10 meters in height with correspondingly smaller wavelengths (Twichell et al., 1987). Megaripples are smaller sand waves that have heights of less than 1 meter and wavelengths of 1 to 15 meters between wave crests. Sand waves may move or migrate at a rate of 12 meters per year, while portions of sand waves may move as much as 60 meters per year (Twichell et al., 1987).

Sand waves and megaripples are absent where surface tidal currents are less than 40 centimeters per second and typically are found in water that is less than 60 meters deep. Sand waves and sand ripples exist in the Great South Channel and on Nantucket Shoals, where surface tidal currents exceed 60 centimeters per second, where sand waves are 5 to 10 meters high (Figures 14a and 14b, Twichell et al., 1987). In the floors of the troughs or depressions between sand wave crests, gravel lag deposits are often found, representing larger heavier particles left behind when the lighter finer sand is swept forward by currents to form the sand waves. Sand waves may build up on both sides of the crests where the ebb tidal current and the flow tidal current are roughly equivalent in speed, in which case the crest of the waves may lie obliquely at an angle to the direction of the ebb and flow tidal currents (Twichell et al., 1987).

Similar but smaller sand waves and sand ripples occur on Stellwagen Bank, where the tidal currents are weaker, reaching speeds of 20 to 30 centimeters per second (Auster et al., 2003; Valentine et al., 2001). Using the Seabed Observation and Sampling System (SEABOSS), researchers have found that silver hake, a predator species that feeds on fish and squid, prefer sand wave habitat, possibly because it provides shelter from current flows and from larger predators (Auster et al., 1995; Valentine, 2000). Furthermore, fish size was related to sand wave morphology as well as current velocities, and prey. Studies like this that integrate underwater landscapes with ecology provide far more useful information for resource managers than studies that address only one issue at a time.

These results show that seabed mapping provides resource managers with information on where the best benthic habitat may exist in an area, and how benthic habitat can be impacted by mobile fishing gear. Seabed mapping can be used to monitor long-term use and recovery of benthic habitats over large areas. Seabed mapping has proved highly useful for making management decisions involving commercial and recreational fishing, habitat disturbance, engineering projects, tourism, and cultural resources (USGS and NOAA/National Marine Sanctuary Program, 2003). Seabed mapping is one of the most essential and invaluable tools for understanding, managing and protecting marine habitats. This cannot be overemphasized.

In Nantucket Sound, the USGS has collected information on sediment grain size, using sediment sampling (Figure 15). This study, performed by USGS scientists Larry Poppe and Chris Polloni, is one of the few recent scientific studies centering on Nantucket Sound (Poppe and Polloni, 2000). Their broad survey shows that sand predominates over most of the area, with occasional pockets of silty clay (e.g., in the oval basin west of Nantucket). Gravel deposits also occur as long linear east-west ridges at the eastern end of Vineyard Sound (western end of Nantucket Sound) and gravel also forms mounds here and there around the margins of Nantucket Sound. Yet the Stellwagen studies demonstrate how complex the seafloor geology and habitat are, and how even thousands of sediment samples are inadequate to describe the seafloor environment.

4.8. Issues and Data Gaps

Multisensor seabed mapping techniques have not been applied to studying the benthic habitats of Nantucket Sound, or Vinetard Sound, Nantucket Shoals or large areas of the Great South Channel or Georges Bank. Given the proximity to government scientific agencies and research institutions, this is surprising, but the information gap is probably due to the fact that neither of these areas is located within a marine sanctuary, and the fisheries that once existed in Nantucket Sound have been depleted. This information gap is an important one.

As a result, we know little about the benthic habitats that may be present in Vineyard and Nantucket Sounds and Nantucket Shoals, except indirectly through fisheries information and sediment grain size mapping. We know nothing about the potential impacts to benthic habitat in these areas from mobile fishing gear, which has been documented in the Gulf of Maine (Auster et al., 1996). This is one of the most significant data gaps identified in this literature review.

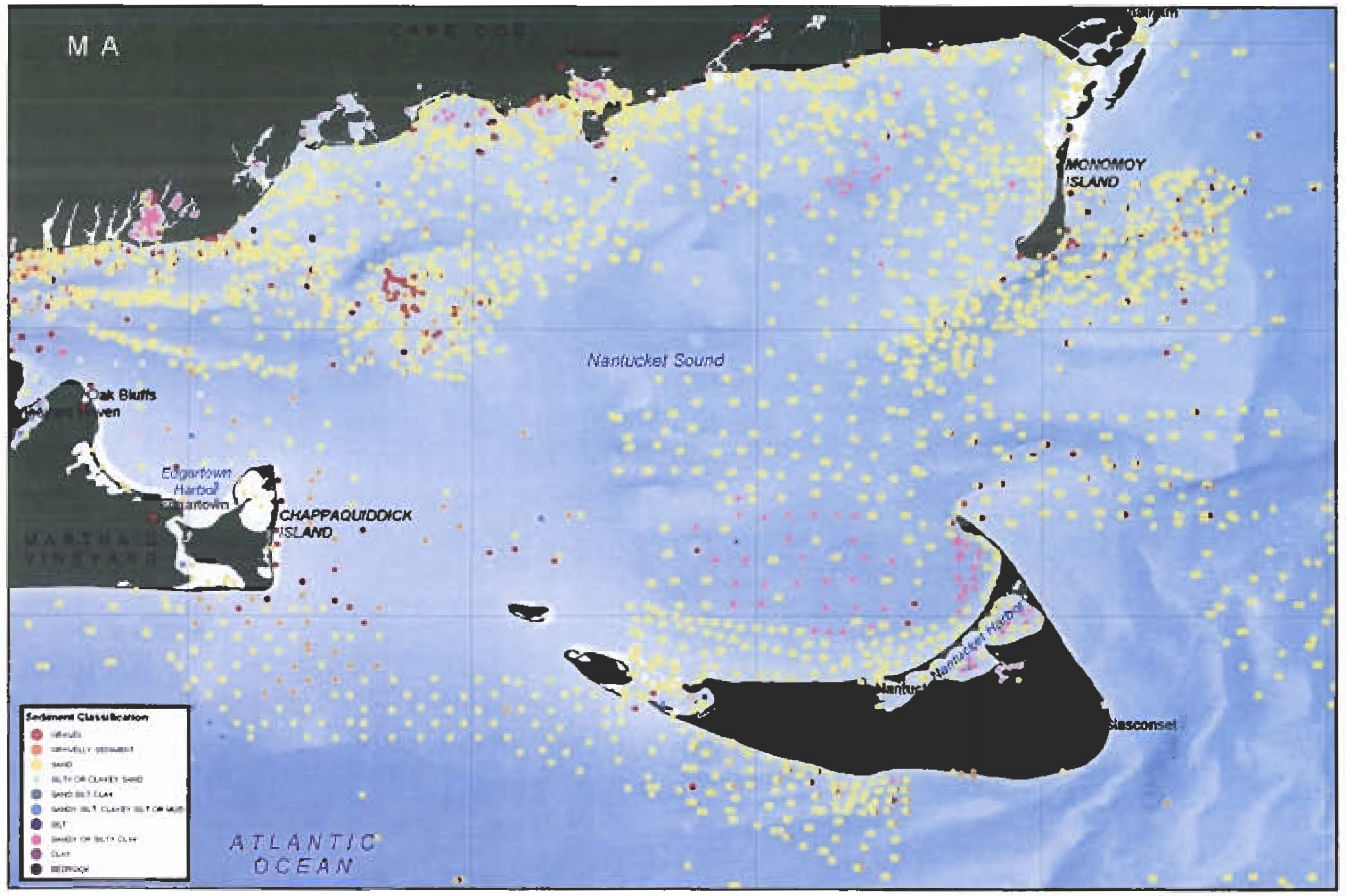


Figure 15. Sediment Grain Size. From Poppe and Polloni (2000).

Sand waves and ripples provide important habitat for fish on Georges Bank and Stellwagen Bank. Do sand waves exist in Nantucket Sound? If so, do the troughs between sand waves, or the gravelly ridges mapped by Poppe and Polloni (2000), provide essential fish habitat? A sidescan sonar study was performed for a proposed wind energy project describes sand waves (Cape Wind Farm DEIR); however, the sidescan sonar data were not provided in the DEIR, and so the existence of such sand waves cannot be confirmed. However, given the tidal currents in the Nantucket Sound and Nantucket Shoals areas (see section on Circulation), underwater sand waves probably do occur. Mapping such sedimentary bedforms would be important for mapping essential fish habitat and benthic habitat.

Are the long gravel and sand ridges remnants of glacial deposits, or are they deposits formed by winnowing by the strong tidal currents? These sand ridges and shoals are probably completely the result of tidal currents, but this is an area that needs further study. The length and east-west orientation of these features suggests that these features are associated with the terminal moraines formed by the retreating ice, since they are roughly parallel with the glacial ice front. It does not seem likely that they are submerged drumlins, like the east-southeast submerged drumlins found in Massachusetts Bay, which reflect the flow direction of the ice sheet in that region (Oldale et al., 1994), because the flow direction of the ice sheet in the Nantucket Sound region was probably north-south. Uchupi and his colleagues found that the sediments of Nantucket Sound represent a complex history related to the inundation of the area as sea level rose during the latest Holocene transgression (Uchupi et al., 1996).

In short, while the sedimentary and benthic habitats of Georges Bank and Stellwagen Bank and portions of the Great South Channel have been studied in depth, only the structural geology, glacial history, and sediment grain size of Nantucket Sound and Nantucket Shoals have been studied to any extent. Benthic habitat of Vineyard Sound, Nantucket Sound and Nantucket Shelf have yet to be characterized at the level of detail of the Stellwagen Bank studies.

5. BATHYMETRY

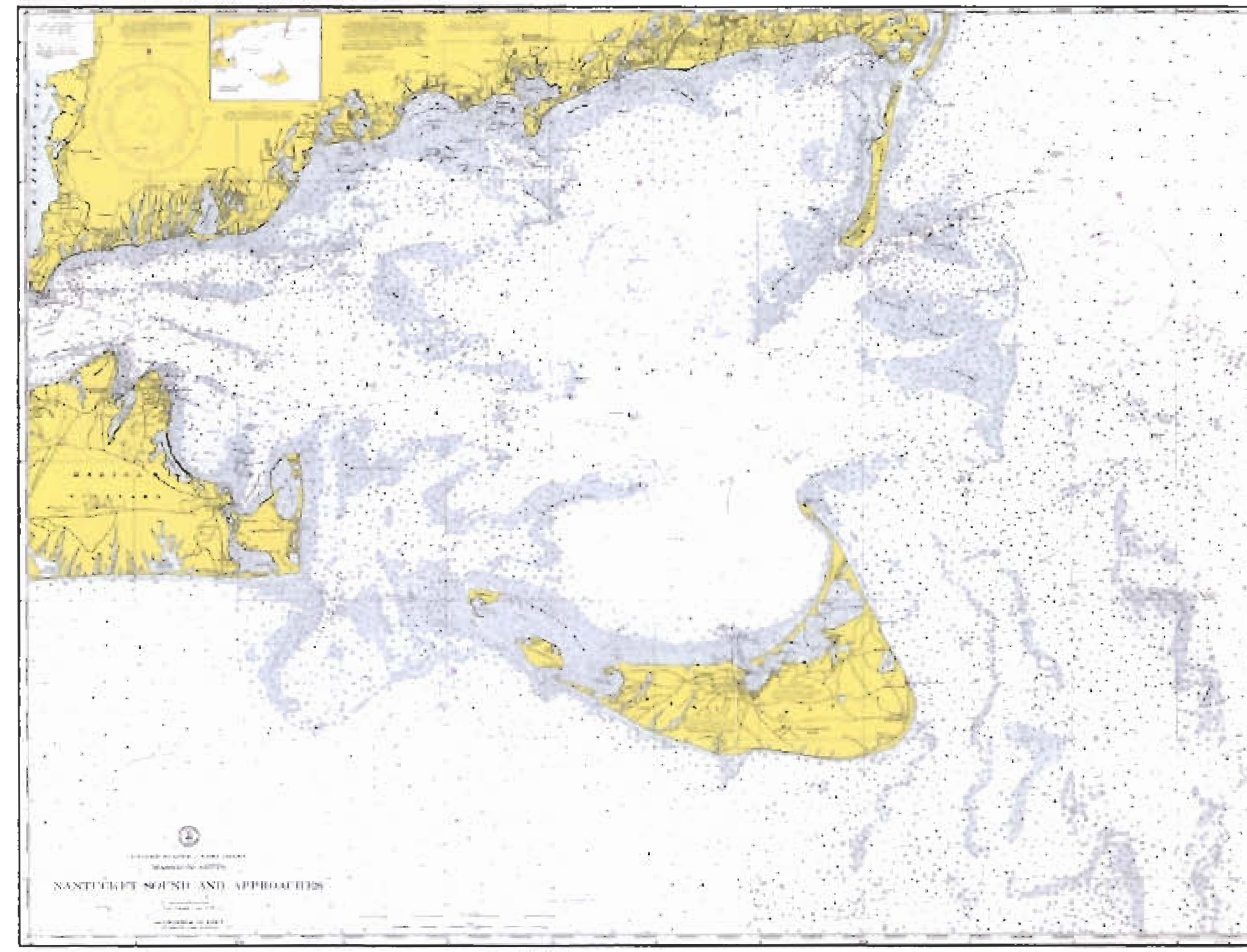


Figure 16. NOAA Bathymetric Chart. U.S. Department of Commerce, Coast and Geodetic Survey Chart No. 1209, 1970.

5.1. Bathymetry Charts

Existing NOAA navigational charts provide bathymetry of the Nantucket Shelf region. Such charts are developed for navigational purposes. A 1970 NOAA bathymetry chart of Nantucket Sound is shown in Figure 16 (U.S. Department of Commerce, Coast and Geodetic Survey Chart No. 1209, 1970). Such maps are useful for largescale assessment, but may be less suitable for evaluating benthic habitat values due to the scale of mapping.

Bathymetric maps show the topography of Nantucket Shoals and Nantucket Sound is best characterized as irregular and broken, with ridges that are both linear and irregularly sinuous, mounds, and plateaus, with channels between these topographic highs. The largest expanses of water that could be called basins are situated in two areas: 1) an oval basin just west of the island of Nantucket, surrounded on three sides by Tuckernuck Shoal, Tuckernuck Bank, and the long horn of Nantucket's spit, and 2) An irregular basin, lying between the above mentioned basin, Lewis Bay on Cape Cod, and Monomoy Island (U.S. Department of Commerce, Coast and Geodetic Survey Chart No. 1209, 1970).

Water depths in Nantucket Sound vary from less than half a meter (1 foot) to approximately 23 meters (70 feet), relative to mean low water (Coast and Geodetic Survey Chart No. 1209, 1970). The deepest areas of Nantucket Sound are found approximately 3 nautical miles due south of Waquoit Bay, at the western end of Nantucket Sound adjacent to Vineyard Sound; approximately 4 nautical miles south of West Bay, approximately 8.5 nautical miles south of West Bay; immediately south of the southern end of Monomoy Island (Butler Hole); several small areas north of Nantucket; and in Muskegat Channel lying off the southeastern end of Martha's Vineyard. With the exception of one or two small areas north of Nantucket, most of these deeper areas lie within long, elongate basins that are probably associated with areas of rapid current flow that have helped to shape these features. Their orientation corresponds with the major directions of tidal current flow into and out of Nantucket Sound (see Section on Physical Oceanography).

5.2. Issues and Data Gaps

A study of how and whether bathymetry has changed over time, throughout the Nantucket Shelf Region, does not appear to have been done. This is important to know because changes in bathymetry and sediment transport can affect benthic habitats. Such a study would also shed light on changes in circulation in response to climate change, the effects of major storms on sediment movement and distribution, and the effects of shallow nearshore sediments on abating storm wave energy.

High-resolution bathymetry data would provide a necessary foundation for many other studies, such as habitat mapping, and for resource management.

Long-term studies of bathymetry would also be useful for evaluating whether sand transport from the shelf to nearshore regions can occur via waves, tides and currents; this is a little-studied area of coastal geology, since most attention typically has focused on sand transport from nearshore to shelf regions. A recent workshop on coastal change addressed such issues and the need for developing an ocean observatory system (Workshop on "The Moving Shoreline: Coastal Change in Response to Rising Sea Level, April 26 – April 29, Woods Hole Oceanographic Institution, Rob Evans, Department of Geology and Geophysics, Conference Chairman).

Research data buoys ready for deployment.
photo: NOAA library

6. PHYSICAL OCEANOGRAPHY

Physical oceanography is the science of the movement of the sea. It deals with circulation, tides, waves, currents and the physical processes that cause the ocean to move. Physical oceanographers in particular seek to understand why and how the ocean moves, and are therefore most interested in processes. Examples of important processes include:

- Advection (mixing of different water masses);
- Stratification (formation of layers of water with different properties);
- Buoyancy (tendency of a less dense body of water to rise relative to a denser body of water);
- Tides (created by the constantly changing gravitational attractions of moon, sun and earth as these move relative to each other);
- Gradient-driven flow (water flows down to a lower area due to gravity);
- Coriolis force (the earth's daily rotation under a body of water causes that water body to slowly spin clockwise or counterclockwise); and
- Interactions between some or all of the above processes.

These major physical oceanographic processes can affect the chemistry, ecology, geology, and climate of a region. Very often, understanding the physical oceanography of an area, one can predict the chemistry, ecology, sedimentation, and erosion of a region. Physical oceanographers rely upon field measurements of the properties of water: current velocities, tidal ranges, wave heights, water temperature, salinity, density and so on. Such data is combined with knowledge of basic physical processes that cause water masses to move. Computer mathematical models are created to understand how water masses move and change over time, based on selected processes and field data. The results of such models are compared with observations to see whether the models accurately match observed conditions.

Scientific knowledge concerning the physical oceanographic processes of the Nantucket Shelf Region is patchy. Much is understood about the physical oceanography of the Gulf of Maine (and by extension Nantucket Shoals and the eastern margin of Nantucket Sound) and Georges Bank. In a general sense and at a large scale, the physical oceanography of the New England continental shelf is well understood. Specific areas have been studied more than others, for example, the off-shelf currents leading down to the submarine canyons at the head of the continental slope (see studies by Brad Butman and others).

However, a major information gap exists where Nantucket Sound and Vineyard Sound are concerned, largely due to the lack of modern detailed and focused scientific studies aimed at understanding the physical oceanographic processes in these areas. We probably know more about the physical oceanography of Georges Bank, Stellwagen Bank, and the Gulf of Maine than we do about our own backyard, Nantucket Sound and Vineyard Sound.

Research data buoy deployment.
photo: NOAA library

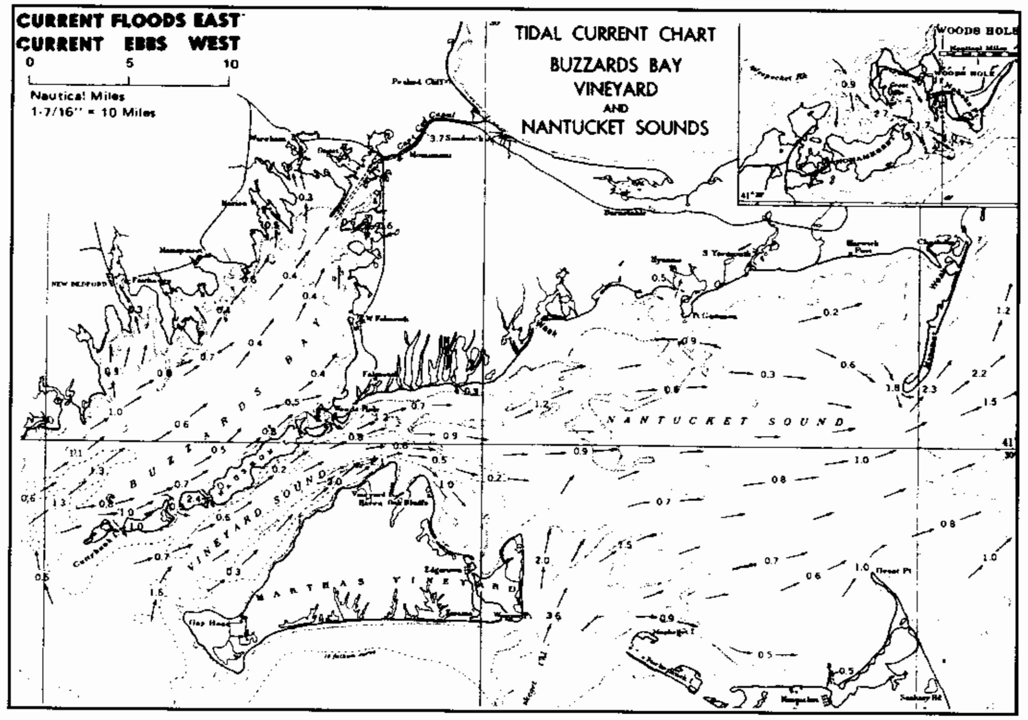


Figure 17. Tidal Current Chart. Buzzards Bay, Vineyard and Nantucket Sounds. 3 hours after flood starts at Pollock Rip Channel or 1 hour after low water at Boston. Velocities shown are at Spring Tides. See Note at bottom of Boston Tables: Rule-Of-Thumb for Current Velocities. (Pollock Rip Ch. is SE of Monomoy Point). From Eldridge (2003).

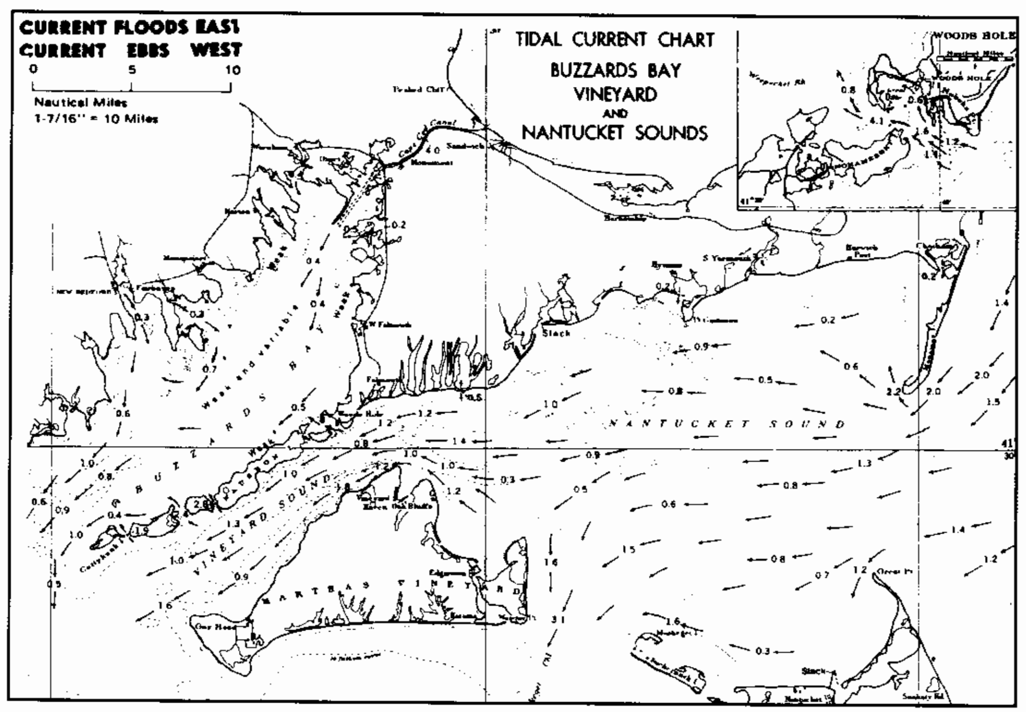


Figure 18. Tidal Current Chart. Buzzards Bay, Vineyard and Nantucket Sounds. 3 hours after EBB starts at Pollock Rip Channel or 1 hour after high water at Boston. Velocities shown are at Spring Tides. See Note at bottom of Boston Tables: Rule-Of-Thumb for Current Velocities. (Pollock Rip Ch. is SE of Monomoy Point). From Eldridge (2003).

6.1. Vineyard Sound, Nantucket Sound and Nantucket Shoals

The tidal range in Vineyard Sound and Nantucket Sound is relatively small, ranging from 1.5 to 3 feet in various areas, with lower tidal ranges occurring on shorelines facing the open ocean and higher tidal ranges occurring in coastal embayments and other semi-enclosed areas. Nantucket Sound and Vineyard Sound receive little river runoff; therefore, despite the low tidal range, their circulation is dominated by strong (upwards of 2 knots) reversing semi-diurnal tidal currents (Bumpus et al., 1973). The net drift movement of water is towards the east, amounting to about 200 cubic meters per tidal cycle, or about 5 percent of the total easterly and westerly tidal flow (Bumpus et al., 1971). Salinity ranges from 30 to 32.5 parts per thousand. There is little or no vertical stratification of the water column due to the turbulent mixing by tidal current over the uneven bottom of the sounds, and meet Pritchard's definition of a Type D vertically homogenous estuary (Pritchard, 1955).

In Vineyard Sound and Nantucket Sound, the ebb tide current flows to the west while the flood tide current flows to the east, towards the Great South Channel (Figures 17 and 18, Eldridge, 2003). During the ebb tide, a tidal current flows south between Nantucket and Martha's Vineyard, through Muskegat Channel, into the Nantucket Shoals region, reversing during the flood tide. Average maximum current velocities range from 2 knots (103 centimeters per second) on flood tides in Pollock Rip Channel southeast of Monomoy, to 4.5 knots (231 centimeters per second) on flood tides in Woods Hole channel, at the western end of Vineyard Sound and sometimes exceeding 7 knots (360 centimeters per second) in the latter area (Eldridge, 2003). On Nantucket Shoals, tidal currents also dominate water movement and surface tidal currents exceed 60 centimeters per second (Twichell et al., 1987).

These tidal current speeds are much faster than the minimum current speed needed to form sand waves and megaripples, which is 40 centimeters per second (Twichell et al., 1987), so where there is plenty of sand available, it is likely that sand waves and megaripples have formed in Vineyard Sound and Nantucket Sound. Since the ebb and flood tide currents are almost equally strong (easterly flow is slightly greater), it would not be surprising to find sand waves that have built up sand on both sides of the wave crest, as occurs in Georges Bank (Twichell et al.,1987). However, no scientific studies of sedimentary bedforms and benthic habitat in Nantucket Sound or Vineyard Sound have been done, as mentioned previously.

6.2. Gulf of Maine

The Gulf of Maine is a marginal sea that is nearly isolated from the Atlantic Ocean by Georges Bank, Browns Bank, the Great South Channel ridge, and Cape Cod. Its waters are cold, chilled by both the Labrador Current and by severe winter cooling brought about by the gulf's location in the lee of the North American continent and isolation from the warmer deeper waters of the North Atlantic Ocean (Brooks, 1992). The gulf contains three major basins with varying depths: Wilkinson Basin (275 meters deep), Jordan Basin (275 meters deep), and Georges Basin (379 meters deep).

The main connection between the Gulf of Maine and the Atlantic Ocean is the Northeast Channel, a glacially-scoured drowned valley with a sill depth of 230 meters. At this sill depth, deeper Atlantic slope water can enter the Gulf of Maine. The Great South Channel is shallower and only allows limited exchange of water with the upper layers of the Atlantic, with a sill depth of about 70 meters, despite the fact that it is a low point in the submarine ridge that runs from Nantucket Shoals to Georges Bank (recall its former role as a water gap in pre-Pleistocene times, according to O'Hara and Oldale (1987)).

Non-tidal circulation in the Gulf of Maine is basically counterclockwise, with a smaller clockwise gyre in the eastern gulf, and counterclockwise circulation in the western and southern gulf (Brooks, 1992). Flow around the edge of Georges Bank is clockwise. At the extreme southern end of the Gulf of Maine, water flow diverges from the main gulf counterclockwise circulation and follows the edge of the Nantucket Shelf region south and then west (Figures 19 and 20 from Bigelow (1927) and Brooks, 1992). The divergence is an area where upwelling of deeper nutrient-rich water occurs in response to the diverging water masses, and is thus an area where production should be higher.

The contour-hugging current flows around Nantucket Shoals, along depth contours of 20 meters or greater, bending around the Shoals much as a ship might avoid the Shoals. In the spring and summer, surface currents become stronger as heating and stratification increase, while during the winter the gyre-like circulation weakens and the surface water inside the gulf drifts slowly seaward over the banks (Brooks, 1992).

In the nearshore areas of the Gulf of Maine, fresher waters are less salty and dense, and during the summer form a thin layer on top of the saltier, denser Atlantic ocean water entering the gulf through the Northeast Channel (which is called Maine Bottom Water). In the winter, due to intense cooling of water at the surface of the ocean, chilled water sinks and forms an intermediate layer of water called Maine Intermediate Water, which by its sinking causes the overturn or mixing of nearly two-thirds of the water column.

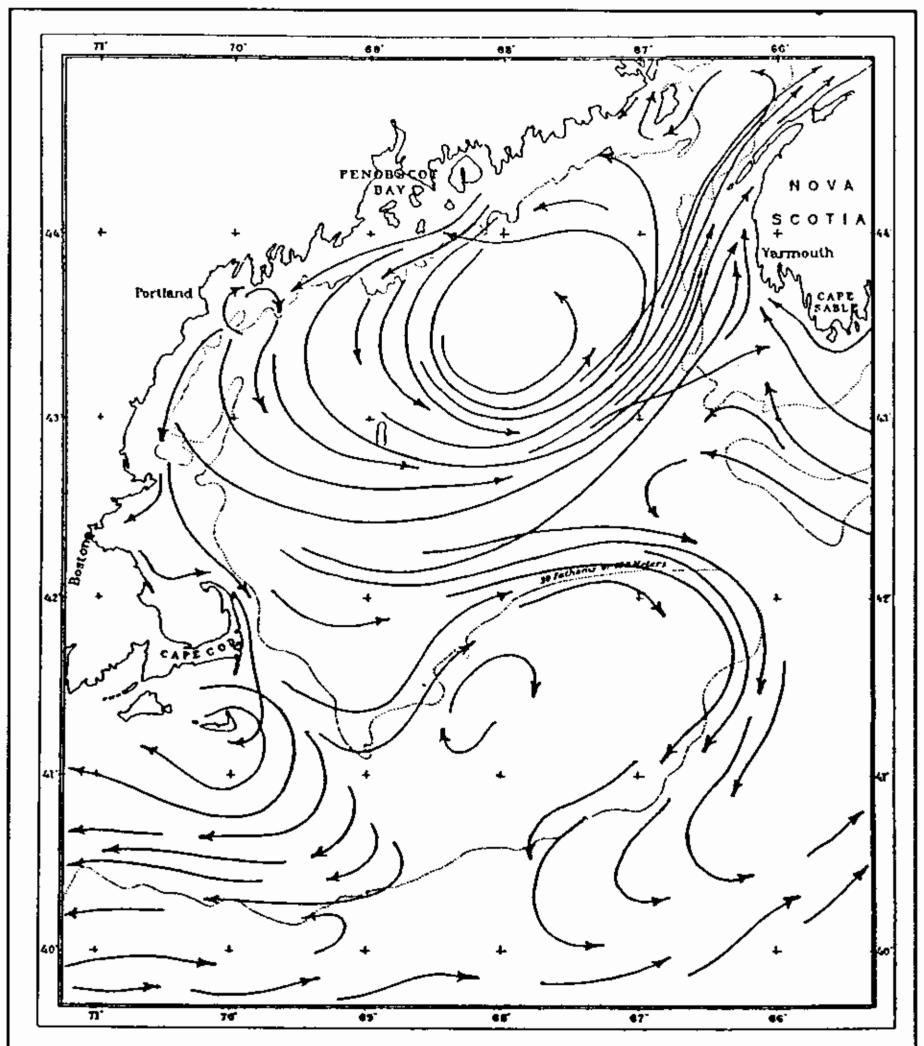


Figure 19. Bigelow's (1927) classical circulation schematic for the Gulf of Maine region in summer months, based on multiple experiments with surface drift bottles, hydrography, and plankton distributions. Bigelow (1927) and Brooks, (1992).

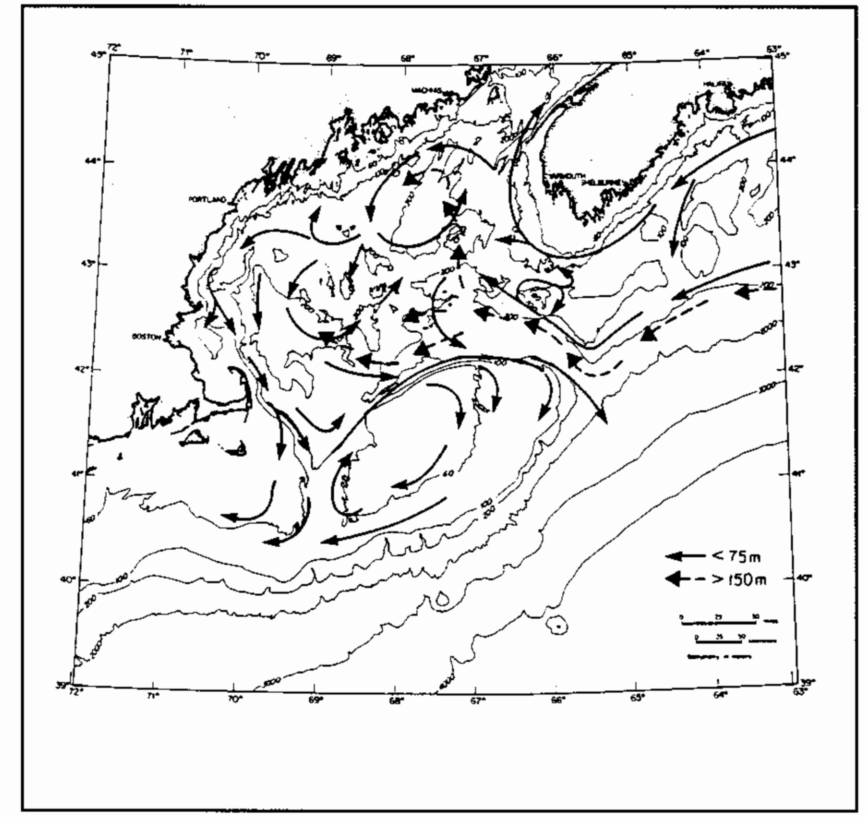


Figure 20. Schematic map of the summer subtidal circulation in the Gulf of Maine. The circulation is separated into a near surface component (at depths below 150 m; dashed lines) showing the flow of dense salty slope water. The net deep inflow of slope water entering the Gulf of Maine through the Northeast Channel is mixed vertically by several mechanisms (e.g., coastal upwelling, seasonal overturning, boundary mixing) and leaves the Gulf of Maine in the flow above 100 m. No comparable map exists for the circulation during other seasons. Brooks (1992).

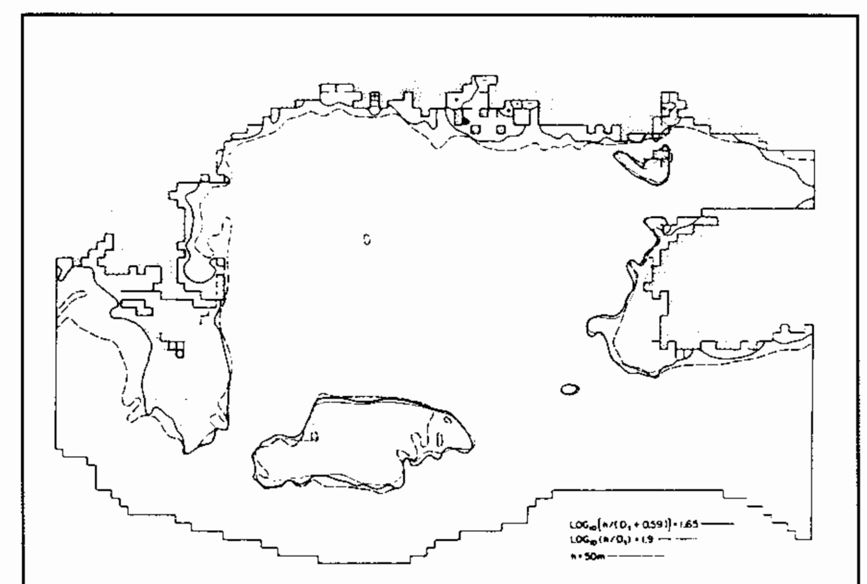


Figure 21. Predicted frontal positions for tidal and summertime wind mixing, using tidal dissipation rates calculated from Greenberg's (1983) model. The positions of the log (h/Dt) = 1.9 contour (…) and the 50 m isobath (---_ are also shown. Figure from Loder and Greenberg (1986). Brooks (1992).

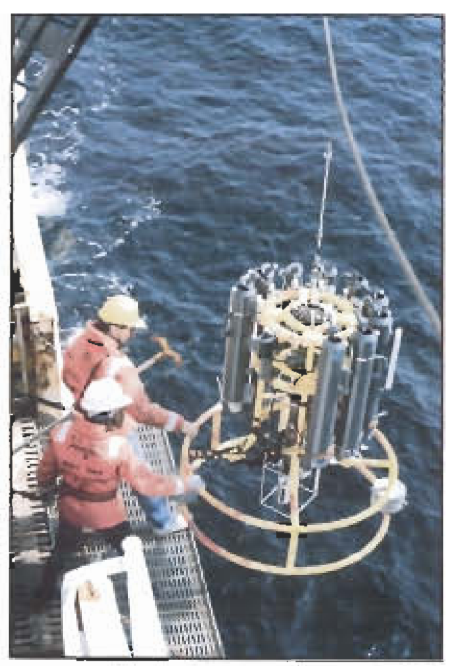
In the Gulf of Maine, current speeds in upper surface currents in areas away from the banks are typically 30 to 50 centimeters per second, but in narrow channels and over sills, deep current speeds can be several times greater.

The Gulf is also known for its tidal resonance, which means that the tides are reinforced or amplified due to the basin's configuration and orientation (long axis running from northeast to southwest) relative to the moon's orbit about the earth (apparent east to west motion). Tidal heights increase eastward, exceeding 15 meters in the Bay of Fundy. Tidal currents resulting from the amplified tides can reach velocities of more than 1 meter per second in the upper Bay of Fundy, shallower areas and inner edge of Georges Bank, and the western end of the Scotian Shelf, while in the southwestern gulf the tidal currents are typically a few tens of centimeters per second (Brooks, 1992).

6.3. Tidal Mixing Fronts

Tidal fronts are formed when tidally well-mixed water meets less well-mixed water. Due to the large tidal variation and rapid tidal currents, there is vigorous tidal mixing of the waters of Georges Bank, the western Nova Scotia shelf, and most of the Bay of Fundy and small areas along the coast of Maine. Where these tidally well-mixed waters meet the stratified fresher water along the coast or the upper warmer water layer during the summer, tidal fronts form. Wind-mixing also causes water to overturn, or convect. An example of wind-mixing is blowing across the top of a cup of coffee with a layer of cream added; the cream disperses downward because the "wind" creates friction along the liquid's surface, which causes the liquid to move, which displaces liquid, leading to convection.

Mixing throughout the vertical water column is thorough during the winters, due to wind-driven mixing and the convection brought about by cold surface water sinking to the bottom. When wind-mixing is added to tidal mixing, the resulting tidal fronts are shown in Figure 21 (Brooks, 1992). Tidal fronts occur in the above-mentioned areas, and also in some eastern Maine coastal bays, over the cap of Browns Bank, near Grand Manan Island, and Nantucket Shoals. A tidal mixing front was observed along the eastern edge of Nantucket Shoals during the SCOPEX oceanographic cruises, indicating tidally mixed waters inside the area of Nantucket shoals (Chen et al., 1994a, b).



Physical Oceanographers recovering a water sampling apparatus.
photo: NOAA library

Thorough mixing of ocean layers is important for stimulating productivity of phytoplankton and zooplankton and the ensuing food chain. As Brooks (1992) says, "*One of the important consequences of the tidal stirring is to bring deep dissolved nutrients upward into the surface layers, where the enhanced light can result in higher biological productivity, so that the areas near and inside the tidal fronts shown in Figure 6* (Figure 21 in this review) *also tend to support high primary and secondary production. For example, the tidally-stirred waters of the eastern gulf and Georges and Browns Banks support one of the world's richest fisheries (Yentsch and Garfield, 1981)*." (Brooks, 1992). Note that the area inside the tidal front boundary in Figure 19 includes the Nantucket Shelf Region (e.g., Nantucket Shoals, Nantucket Sound, Vineyard Sound), and Buzzards Bay.

Physical oceanography, therefore, suggests that the Nantucket Shelf Region should be a biologically productive area, due to thorough mixing of the water column by strong tidal currents. Vigorous mixing promotes high oxygen levels in the water column, and in general, well-mixed, well-aerated water bodies can support greater numbers and more diversity of organisms than water with low or no oxygen. The prediction concerning enhanced productivity due to high mixing rates is borne out by remote sensing observations of primary productivity (chlorophyll concentrations) in the Nantucket Shelf Region, discussed in a later section in this review. Biodiversity is discussed in a later section as well.

6.4. Shelf-Slope Currents

In the Nantucket Shelf Region, water depths are generally too shallow to allow intrusion of deeper slope water, such as the slope water intrusion that occurs at the north end of the Gulf of Maine, over the Northeast Channel sill (Brooks, 1992). But the reverse - flow of water from the shallow Nantucket Shelf Region to deeper water - is conceivable, perhaps by analogy with the Gulf of Maine situation where winter chilling creates a dense layer that sinks to form the cold Maine Intermediate Water layer.

USGS studies of the outer continental shelf south and southwest of Martha's Vineyard indicate that so-called "cross-shelf currents" flow down off the edge of the continental shelf towards the continental slope, particularly in areas where there are preexisting submarine canyons cut into the edge of the continental shelf (Butman, 1988; Butman, 1987; Bumpus, 1973). Tidal forces appear to be responsible for causing the currents, which are found in water depths of 200 to 300 meters. In a 1972 study, a shelf-slope current was measured at 950 meters depth on the continental slope (Wunsch and Hendry, 1972). The Nantucket Shoals Flux Experiment also documented a net downslope current at 200 meters depth (Beardsley et al., 1985). Although such currents are typically weak, with speeds of 1 to 5 centimeters per second, they carry continental shelf materials (sediments, nutrients, organisms, organic detritus) towards the deeper slope environment. Such off-shelf currents that transport water and suspended sediments into the upper continental slope environment appear widespread off the New England shelf (Butman, 1988; Ross, 1968).

Turbidity currents, which are underwater flows of sediment-laden water from underwater landslides and river deltas, can travel hundreds of miles, depositing sediments far over the abyssal ocean plain. Underwater submarine fans on the continental slope, continental rise, and abyssal plain represent the accumulation of sediment deposited by many such turbidity events. In many cases, large submarine fans such as the Hudson Canyon fan, represent the seaward end of the deposits carried by rivers. Turbidity flows originating from the Gulf of Maine have deposited sediments far out over the Atlantic slope, rise and abyssal plain (Horn et al., 1971, in Leeder, 1982).

6.5. Issues and Data Gaps

Physical oceanographic studies of Nantucket Sound / Vineyard Sound water mixing, water residence time, seasonal changes, and transport to other ocean areas, such as the Great South Channel and outer continental shelf and slope, are lacking. Such studies would be invaluable for evaluating current and past productivity of the region, and for predicting how productivity will change over time. There are no studies, for example, of how much nutrient loading Nantucket Sound and Vineyard Sound can withstand before showing impacts; up to now, we have assumed that the rapid tidal currents will flush pollutants out of the sounds. Also, adjacent areas may eventually be impacted eventually.

Although tidal currents flow between Nantucket Sound and the southern Gulf of Maine and the Great South Channel, the interactions between Nantucket Sound and the other two bodies of water have not really been investigated. This is a significant information gap, particularly given coastal nutrient inputs into Nantucket and Vineyard Sounds and high primary productivity in the Nantucket Sound-Vineyard Sound area, based on remote sensing of ocean color. The proximity of Nantucket Sound to the Great South Channel, where high nutrient and chlorophyll concentrations support copepod blooms, which in turn support high densities of right whales (Kenney et al., 1995; Kenney and Wishner, 1994; Durbin et al., 1994a and 1994b;

Wishner et al., 1994; Macaulay et al., 1994; Winn et al., 1994; Kenney and Winn, 1986; Kenney et al., 1986), suggests an important ecological connection between the three bodies of water. But this remains to be investigated.

The relationship between currents and sedimentary bedforms, such as sand waves, ripples, depressions, and sediment grain size needs to be investigated because these are key features of benthic habitat for important fish and invertebrate species. There are no studies of this type for Vineyard or Nantucket Sounds.

Studies show that there is considerable transport of continental materials into the deep sea in general. There is no information concerning whether such transport occurs from the Nantucket Sound shallow shelf into adjacent deeper waters. The possible linkage between productivity in shallow continental shelf areas and deeper outer shelf and continental slope areas needs to be investigated further, since there are currents that can transport sediments and other materials to deeper areas of the ocean. Is there a possible linkage between shelf nutrients and slope ecosystems? This is an important topic for oceanographic research into the biogeochemical cycling of nutrients between major regions of the ocean, and certainly bears on deep-sea fisheries on the upper continental slope.

The high degree of mixing in the Nantucket Shelf Region, combined with the high primary productivity in this region, nutrient loading into coastal estuaries of Cape Cod and the Islands, the regional productivity in terms of fisheries, the highly productive Great South Channel attracts endangered Right Whales, suggest that a larger ecoregional approach is needed. A better understanding is needed about how the physical oceanography of Nantucket and Vineyard Sounds dovetails with the regional oceanographic processes of Nantucket Shoals, the Gulf of Maine, Georges Bank, the Great South Channel and the outer continental shelf and slope.

7. CHEMICAL OCEANOGRAPHY

Chemical oceanography is the study of the chemical composition of the sea and, more importantly, the many chemical, biological and physical processes that cause the ocean to differ in composition from area to area. Chemical oceanographers want to find out how much of a particular substance exists in the ocean, how it got there, how long it will take to disappear or be consumed, what affects the composition, and what composition tells us about these other shadowy processes.

Biogeochemical cycling is one particular interest of chemical oceanographers. This refers to the transfer of an element, say, between water, sediments, air and living organisms (acting as "reservoirs" to store and hold an element), and the many physical, chemical and biological processes that carry the element between these reservoirs. Elements such as carbon, nitrogen, sulfur, and certain trace elements, which are the building blocks of living organisms, are of great interest for those who study biogeochemical cycling and chemical oceanography.

The biogeochemical cycling of carbon between the ocean, continental shelf, land plants and organisms, and the atmosphere, is of great interest now, because of the role of carbon dioxide in trapping heat in the earth's atmosphere (global warming). Nitrogen cycling is important in the ocean because of eutrophication – an excess of nutrients, particularly nitrogen, brought about by man's activities.


Oceanographer collecting water samples for analysis. photo: NOAA library

7.1. Older Studies

Chemical oceanographic studies that include the Nantucket Sound region are rare, older and largescale in scope (Kester and Courant, 1973), compared to chemical oceanographic studies of nutrients and organic matter cycling in the Gulf of Maine (Townsend, 1997; Kelly, 1997; Christensen, 1989), nutrients, metals and organic pollutants in Georges Bank (Walsh et al., 1987; Bothner et al., 1987; Farrington and Boehm, 1987), and nutrients in the Great South Channel (Durbin et al., 1995 a and 1995b). Massachusetts Bay and Boston Harbor have been extensively studied in terms of their sediment chemistry and pollutants, because of the monitoring required for the Boston Harbor sewage outfall and the Massachusetts Bay Disposal Site.

The older study by Kester and Courant describes dissolved oxygen concentrations, which are in the range of 5 to 6 milliliters per liter off the Massachusetts coast. Nutrient loading studies of Cape Cod embayments are even more numerous, due to concerns about coastal nutrient loading and eutrophication and thanks to the Massachusetts Department of Environmental Protection (DEP) Estuaries Project and the Cape Cod Coastal Embayment Project (see Cape Cod Commission, 1998). However, none of the coastal embayment studies will examine long-term nutrient loading of Vineyard and Nantucket Sounds.

A good example of a chemical oceanographic process study is that by Christensen (1989), who examined transport of carbon from the continental shelf of the Gulf of Maine into the adjacent continental slope. His approach used measurements of sulfate reduction and carbon oxidation rates in sediments, which store organic matter. Sulfate reduction is a bacterial process that turns organic matter into carbon dioxide and hydrogen sulfide under low-oxygen, reducing conditions in sediments. Christensen's measurements showed that the amount of carbon falling to bottom sediments (the flux, or the carbon received in sediments) was 47 grams of carbon per meter squared per year, and that sediment processes that used carbon and oxygen, including denitrification and carbon burial, totaled 52.1 grams of carbon per meter squared per year – that is, carbon received roughly equaled carbon spent or permanently buried.

Christensen's study suggested that, for the semi-enclosed Gulf of Maine located on a wide shelf, little export of organic carbon to the deep slope might be expected. In contrast, on a narrow shelf like that off the state of Washington, about 22 to 50 percent of the primary production may be exported from the shelf to the slope (Christen, 1989). This type of study looking at nutrient transport is needed for the Nantucket Shelf Region, particularly given concerns about coastal nutrient loading and our untested assumption that strong tidal currents in the sounds will flush all coastal pollutants away.

7.2. Issues and Data Gaps

There is much that could be done to understand the chemical oceanography of Nantucket Sound, Vineyard Sound, and Nantucket Shoals. Chemical oceanographic studies in these areas are non-existent and constitute a significant data gap that should be addressed by ocean managers. We need to know: 1) basic distributions and concentrations of natural compounds, nutrients, and pollutants, and 2) Chemical oceanographic processes that change, distribute or create these materials. The lack of such basic information will hinder any resource management efforts to, say, restore fisheries or other natural resource values.

8. BIOLOGICAL PRODUCTIVITY

8.1. Importance of Productivity Studies in Ecology

Ecology is the study of relationships between living organisms, their activities, and their environment. Ecologists study biological functions and processes such as photosynthesis, respiration, the transfer of energy from primary producers (plants) to herbivores to predators, the rates at which such processes occur, the physical and chemical environments where these processes take place, and the kinds of organisms which are responsible for specific processes. Measuring and understanding biological productivity of different types of organisms is important for judging the success or impacts on a species, for measuring biodiversity, energy transfer between trophic levels, and ecosystem functioning. It is also critical information for resource managers.

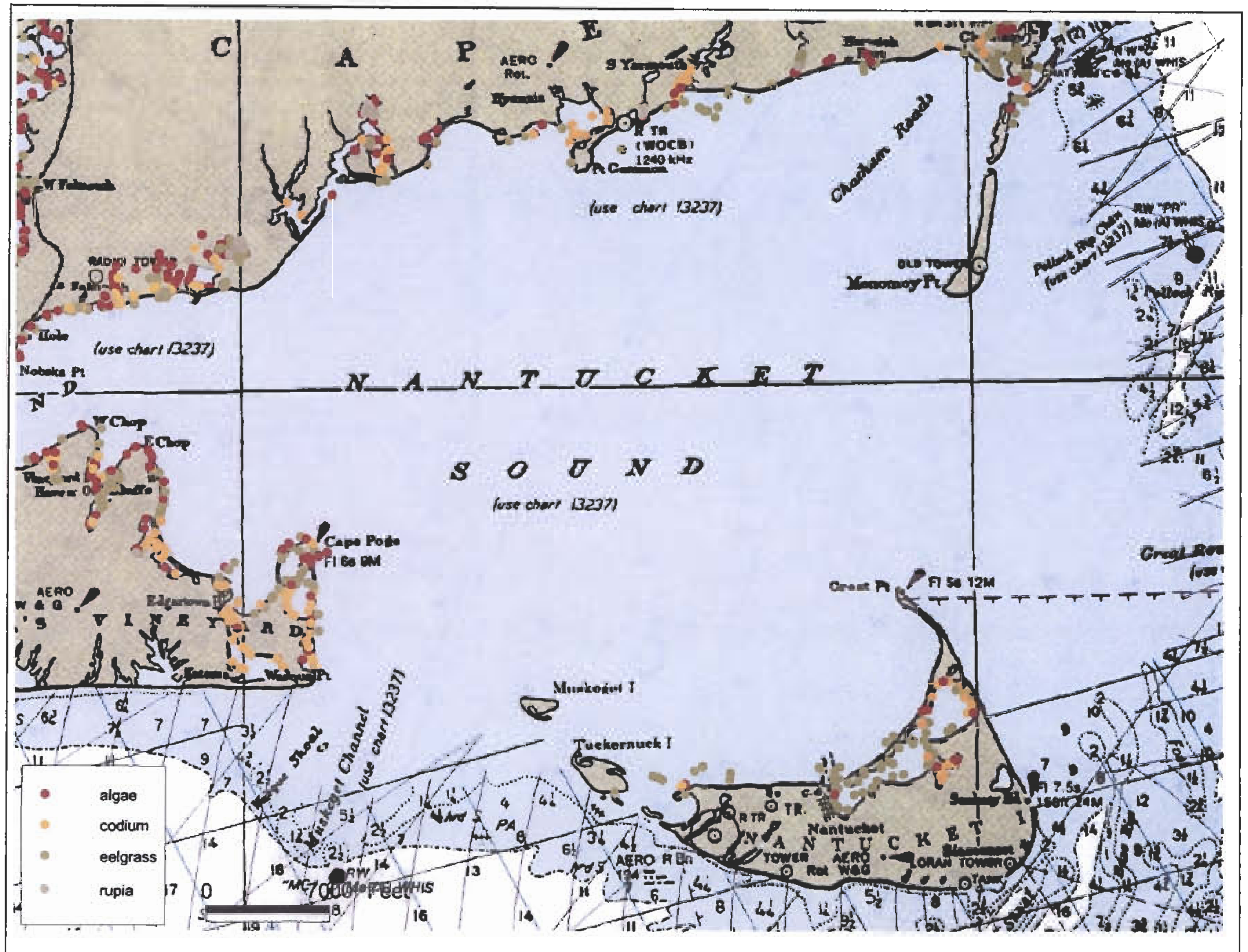


Figure 22. Seagrass and Algae Distributions. Data from MASSGIS, map by Horsley Witten Group.

Ecology also requires sound taxonomy, which is the science of correctly identifying and understanding the ancestral relationships between species of organisms and their evolution. Incorrect identification of a species can lead to incorrect assessments of its role in ecological processes and its place in the evolutionary tree. The science of biological taxonomy has languished in recent decades as ecological studies have gained in prominence and as sophisticated tools for conducting ecological studies have improved and proliferated.

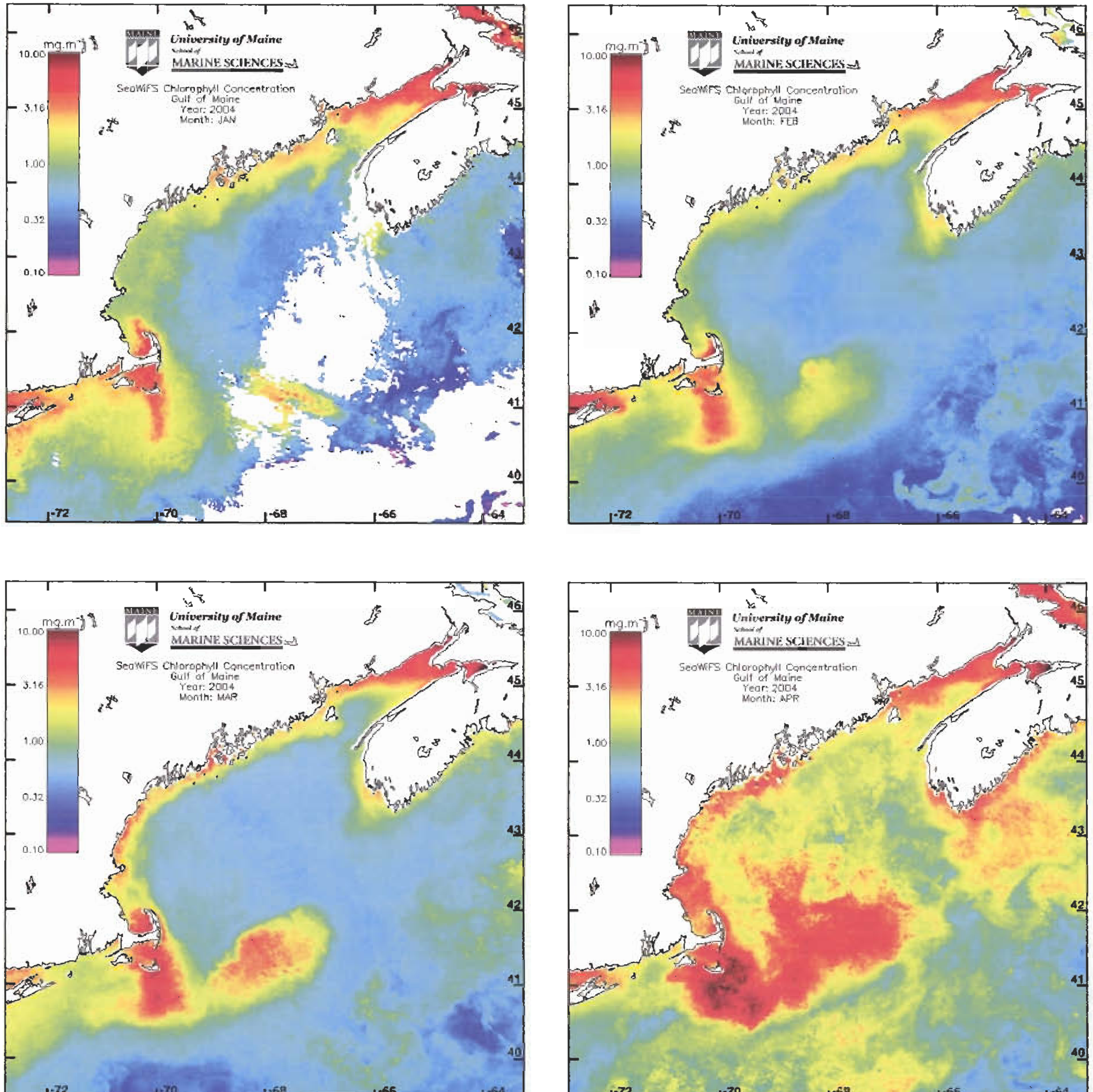
In the open waters of the Nantucket Shelf Region, and particularly in Nantucket Sound, Vineyard Sound, and Nantucket Shoals, marine ecological studies, biological productivity studies and marine invertebrate taxonomic scientific studies are scarce. Studies of birds, marine mammals, and fish are more common. Still, there is no comprehensive study of this area as a regional ecosystem.

8.2. Nutrients and Primary Production

Primary production is the organic matter created through photosynthesis by organisms such as plants, algae and phytoplankton. Primary production forms the basis of the food chain.

Seagrasses, which are vascular plants, provide one important source of primary production, particularly in shallow coastal ecosystems. Eelgrass (*Zostera marina*) is the principal seagrass on the Massachusetts coast, while widgeon grass (*Ruppia maritima*) is present in areas of lower salinity along the Cape Cod and Buzzards Bay coast. Seagrasses provide food and habitat for a wide variety of commercially important fish and shellfish species and for many other plants and animals. Seagrasses require clear water that allows light transmission in order to photosynthesize, although the leaves filter and trap suspended particles, and therefore their growth is limited to the depth where light penetration is adequate to support photosynthesis. In the clearer waters of Nantucket Sound, the depth limit for growth of eelgrass is more than 6 meters below mean lower low water (MLLW), while in the more turbid waters of portions of Buzzards Bay and Cape Cod, the depth limit is less than 3 meters below MLLW.

The Massachusetts Department of Environmental Protection (DEP) Wetlands Conservancy program has completed a project to map the state's submerged aquatic vegetation, working with assistance from NOAA's Coastal Change Analysis Program (C-CAP) and NOAA's Coastal Services Center. The project was conducted from 1994 through 1997, and used aerial photography and fieldwork to map coastal submerged aquatic vegetation (see http://www.state.ma.us/mgis/eelgrass.htm). A MassGIS map showing distribution of eelgrass around Nantucket Sound is shown in Figure 22. Note that the mapping project does not cover areas further offshore because vascular plants do not grow in deeper water (see comment above concerning depth limitation).



Eelgrass was formerly more widespread along the Cape Cod shoreline. Some causes for loss are: 1) Poor water quality, caused by both nutrient loading and the resulting eutrophication and boating activity causing resuspension of sediments, results in reduced sunlight reaching plants; 2) Physical damage to plants from boating and propeller turbulence; and 3) other environmental impacts.

In deeper offshore waters, the most important primary producers are phytoplankton, microscopic aerobic algae of various species, which grow suspended in the water column. Phytoplankton will grow and multiply as long as there are enough nutrients, oxygen and sunlight, and they are not limited in the area which they can cover because they are not rooted. Their growth is limited to the photic zone, the upper 10 meters or so of the water column where enough light of the preferred wavelength can penetrate to allow photosynthesis to occur. Phytoplankton, together with bacteria and other microorganisms, form the all-important base of the food chain in marine ecosystems.

One primary ecological question for any ecosystem is, how much primary production is occurring? Primary production can be measured in many ways, including biomass, growth rates, respiration rates, rate of nutrient uptake, and pigment content. Phytoplankton contain characteristic photosynthetic pigments, of which chlorophyll is the best-known, most abundant and most widely measured. Chlorophyll is frequently used as an indicator of primary productivity in the oceans, although it is not the only pigment that is biologically important.

Chlorophyll in water can be measured using chemical analysis or through remote sensing of ocean color, using satellites. Remote sensing of ocean color, measuring wavelengths that specifically include the color of chlorophyll, can be used to rapidly map large areas of the ocean, in contrast to shipboard water sampling and chemical analysis of chlorophyll. This method, utilizing coastal zone color scanning (CZCS) imagery for chlorophyll, has been used since the late 1970's to remotely map chlorophyll and hence primary production, and to track seasonal and other changes in production (Yoder et al., 2001). For example, Yoder's study focused on a large area of the outer continental shelf off the U.S. east coast, including portions of Georges Bank, the area south and southwest of Martha's Vineyard, and south to Cape Hatteras. This study did not include the Gulf of Maine or Nantucket Sound or the eastern portion of Nantucket Shoals.

Figure 23. Remote sensing satellite data on ocean color (chlorophyll) in the Gulf of Maine and Nantucket Shelf region for January, February, March and April, 2004. These data were downloaded from the Regional Association for Research on the Gulf of Maine (RARGOM) website at http://zeus.mbl.edu/rargom and the Gulf of Maine Ocean Observing System (GoMOOS) website.

Scientists studying primary productivity in the Gulf of Maine have identified several areas where primary production by phytoplankton occurs year-round: Georges Bank, Nantucket Shoals, Browns Bank, and nearshore coastal areas (Thomas et al., 2003). Primary production is affected by bathymetry, temperature, salinity, nutrient concentrations, and tidal mixing of the water column. In deeper parts of the ocean, primary production is limited to the spring and fall. The year-round primary production on Georges Bank is significant because of the important fisheries located here and the stresses on this fishery. The year-round primary production in Nantucket Shoals was noted, but was not a focus of Thomas's study.


SeaWIFS

The SeaWIFS satellite has been used by scientists to map chlorophyll in the Gulf of Maine for several years (see Figure 23 and Thomas et al., 2003). These data, (available online through the Regional Association for Research on the Gulf of Maine (RARGOM) website at http://zeus.mbl.edu/rargom and the Gulf of Maine Ocean Observing System (GoMOOS) website), were collected in early 2004; older data from previous years are available from the website. These maps show that, beginning in January 2004, primary production was already occurring in the shallow Nantucket Shoals and Nantucket Sound area, and on Georges Bank. By April, primary production had expanded to include more of the Massachusetts coast, Georges Bank, and the Gulf of Maine.

This time-series sequence shows that the Nantucket Shelf Region has intense primary production beginning in winter and continuing through the spring and summer. Primary productivity appears to expand outward from this area. Is this apparent expansion real, and why does it occur? The Nantucket Shelf Region also has high primary production compared to other coastal areas. This is significant for fish, shellfish and other marine organisms, and particularly important for commercial and recreational fisheries and for the animals that feed upon these.

8.3. Issues and Data Gaps

So far, there have not been any studies focusing on the primary production within Nantucket Sound, Vineyard Sound or on Nantucket Shoals. It would be important to learn more about such primary production, and how such primary production supports other organisms. If fisheries were to be restored in Nantucket Sound and Vineyard Sound, for example, it would be important to know to what extent the fisheries could be supported by the primary production that occurs here.

The potential effects of coastal nutrient pollution on primary production in Vineyard Sound, Nantucket Sound, or the Nantucket Shelf also have not been addressed through any scientific studies. Coastal nutrient pollution occurs through stormwater runoff, groundwater leachate from septic systems and sewage treatment facilities, boating discharges, agricultural discharges, and other point and nonpoint sources that enter the coastal environment (Natural Resources Council, 2000). Typically, studies of coastal nutrient loading have focused on coastal embayments and nearshore areas, with the exception of monitoring studies of wastewater discharges from ocean outfalls such as the Boston Harbor sewage outfall. Although Nantucket and Vineyard Sounds are swept twice-daily by vigorous tidal currents, the long-term cumulative effects of nutrient inputs on these coastal ecosystems should be investigated. A long-term Ocean Observatory would be suitable for performing such long-term monitoring.

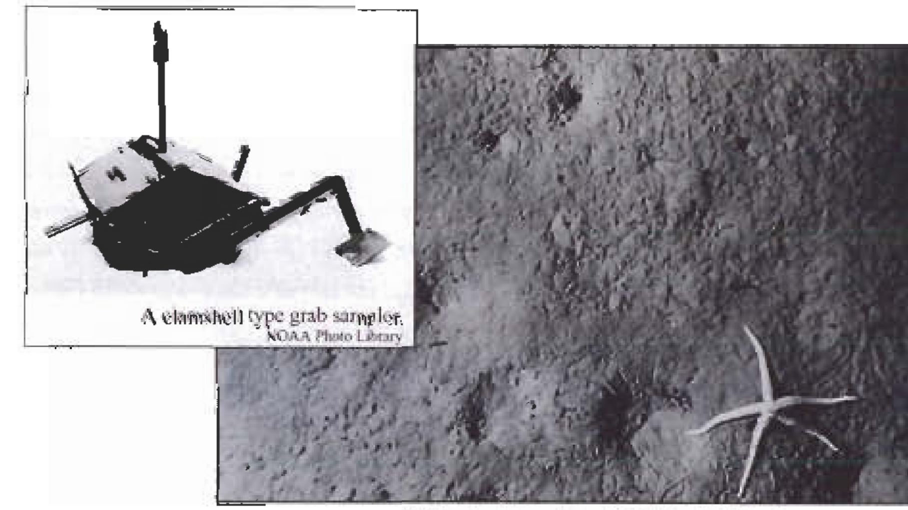
9. BENTHIC FAUNA

9.1. Background

Benthic fauna include invertebrates and certain fish species which live on or in bottom sediments. Benthic fauna include many trophic types: those which graze on algae (grazers), those which strain seawater to get the plankton (filter-feeders), those which feed on plankton and organic matter (suspension-feeders, detritivores), predators, and scavengers. Benthic fauna are an important food source for fish, marine mammals and birds.

Studies of benthic fauna in the Nantucket Shelf Region, focusing on Georges Bank, are summarized by Theroux and Grosslein (1987). In 1871, the U.S. Fish Commission was established to determine the causes of decline in certain fisheries, including investigating benthic fauna; prior to this, benthic faunal studies were primarily done by academic researchers and private scientific societies. After World War II, the Commission's work was expanded, with an emphasis on quantitative population estimates. The Bureau of Commercial Fisheries and the present National Marine Fisheries Service, the successors to the U.S. Fish Commission, continued to investigate benthic fauna due to interest in fisheries, oil drilling, marine mining, and ocean dumping in the Georges Bank-Cape Cod area (Theroux and Grosslein, 1987).

More recent programs investigating the benthic environment of the New England shelf include NOAA's Northeast Monitoring Program (NEMP), the National Marine Fisheries Service' Marine Mapping Assessment and Prediction Program (MARMAP), the Ocean Pulse Program (OP) of the Northeast Fisheries Center (NEFC), and the Woods Hole Oceanographic Institution's Georges Bank Study Group. Benthic sampling for benthic fauna studies has been done at several hundred stations in Nantucket Sound, Nantucket Shoals, the southern New England shelf, Georges Bank, and the Gulf of Maine (reviewed in Theroux and Grosslein, 1987; Pratt, 1973).


A clamshell type grab sampler. NOAA Photo Library

Seafloor image southeast of Nantucket Island. NOAA Photo Library

These studies show that on Georges Bank and the New England region, among 39 groups of benthic macroinvertebrates, four are typically predominant: annelids, crustaceans, mollusks, and echinoderms. However, depending on a number of other factors, such as sediment grain size, water temperature, bathymetry, and whether biomass or numerical densities are used, the relative percentages of these groups varies from area to area (Therou and Grosslein, 1987).

9.2. Effect of Sediment Type

Sediment type is one of the most important determinants of the distribution and type of bottom-dwelling invertebrates, although water depth, water temperature and other physical and biological factors are important as well. On Georges Bank, for example, coarse to fine sands support the highest biomasses of macroinvertebrates; the coarser the sand, the higher the biomass supported (e.g., coarse sand supports a benthic biomass of 371 grams per meter squared (g/m^2), while fine sand sustains a mean biomass of over 220 g/m^2). Silt and clay support a moderately high biomass of about 200 g/m^2. Mean densities of individuals are highest in the coarsest sands (exceeding 2,000 individuals per meter squared) and decrease as grain size decreases (e.g., clay supports 775 individuals per meter squared) (Theroux and Grosslein, 1987).

Sand fauna are benthic faunal species which are found on clean sand in water depths shallow enough to allow sediment transport to occur at least intermittently (Pratt, 1973). Such habitat is found from sandy beaches offshore to depths of several meters of 30 to 50 meters offshore, depending on exposure. Nantucket Shoals and much of Nantucket Sound and Vineyard Sound and the area south of the Elizabeth Islands provide such sand habitat. Other areas include the shelf areas connecting Cape Cod, Block Island and Long Island.

Sand movement is characteristic of these areas, as evidenced by ripple marks and sand waves, and sediment and water movement is significant. Animals that live in such areas must be adapted to such changing dynamic conditions where burial or undermining of the organism may occur frequently. The benefits of living in such a dynamic environment include high oxygen levels in the water column and in sediments, and abundance of suspended food particles (Pratt, 1973).

Surf Clams. NOAA Photo Library

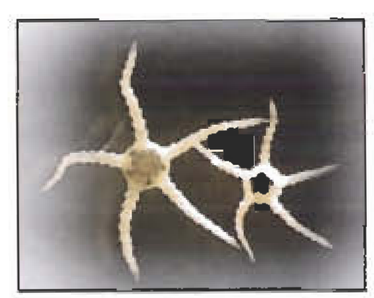
Important sand fauna species from Nantucket Shoals, Georges Bank and other areas of the sandy shelf region extending from Cape Cod down to Long Island Sound are listed below (from Wigley, 1958, as summarized by Pratt, 1973):

1) Polychaete worms: *Scoloplos fragilis, Nephtys bucera, Nephtys picta, Nereis arenaceodonta, Sthenelais limicola, Spiophanes bombyx, Ophelia, Goniadella, Clymenella* sp., *Aricidea* sp., and *Magelona* sp. (deposit feeders);
2) Bivalves: *Spisula solidissima* (surf clam); *Astarte castanea; Ensis directus* (razor clams; suspension feeders). *Tellina agilis* (deposit feeder).
3) Gastropoda: *Polinices duplicatus* and *Lunatia heros* (predators of bivalves).
4) Amphipods: haustorids (suspension feeders), phoxocephalids and lysianassids (deposit feeders and scavengers).
5) Decapods: *Crangon septemspinosus* (shrimp) and *Cancer irroratus* (crab) (omnivores and scavengers).
6) Echinoderm: *Echinarachnius parma* (Sand dollar, deposit feeder).
7) Ascidians: *Amaroucium* (sea pork) and *Mogula arenata* (sea squirt or tunicate) (suspension feeders).
8) Anthozoa: *Paranthus rapiformis* (anemone) (suspension feeder) in southern area (Mid-Atlantic region).

Silty sand is sand that contains up to 25% silt. The occurrence of a significant amount of fine-grained silts generally indicates that the wave and current energy regime is less than in an area where sand or gravel predominate. The energy regime in an area of silty sand is typically less than the energy regime found in sandy areas. However, sandy areas that are located in deeper water may have moderate energy regimes like the energy regimes found in silty sands or sandy silts closer to shore. In such cases, a quiet deep sandy area may have fauna similar to the fauna found in silty sand habitats (Pratt, 1973).

Benthic macroinvertebrates that are found in silty sand include suspension feeders and deposit feeders living in tubes and burrows. There is often vertical structure within the infaunal community. The types of benthic organisms found in silty sands off southern New England in water depths of 40 to 58 meters includes polychaetes (deposit feeders), bivalves (suspension feeders), including the ocean quahog (Arctica islandica), amphipod crustaceans (deposit feeders, suspension feeders), anemones (suspension feeders), and sea cucumbers (deposit feeders) (Wigley and McIntyre, 1964). Silty sands provide important habitat for the benthic organisms that provide food for fish. Northern groundfish (e.g., cod, haddock, hake, yellowtail flounder, lobsters and crabs) feed on benthic organisms found on silty sands during the winter (Pratt, 1973).

Silt-clay sediments are not common or extensive in offshore waters, being rather characteristic of estuarine sediments and deeper shelf and slope sediments. However, there is an area with a high silt-clay content 40 miles onto the shelf in Southern New England (i.e., the Mud Patch). Silt-clay sediments in deeper shelf and slope areas are not necessarily comparable with silt-clay sediments in shallower estuaries and nearshore environments, because the deeper shelf and slope sediments may represent deposits laid down during lower sea level during a glacial period (summarized in Pratt, 1973; McMaster and Garrison, 1966; McKinney and Friedman, 1970).



Sea Stars. NOAA Photo Library

Characteristic silt-clay benthic fauna include deposit-feeding echinoderms (heart urchin, *Briaster fragilis*), brittle stars *(Ophiura sarsi, O. robusta,* and *Amphiura otteri)*, sea star (*Ctenodiscus crispatus*), deposit-feeding polychaetes and bivalves. Wigley and MacIntyre sampled this fauna off southern New England at 69 to 99 meters water depth, and found high densities of mollusks, mostly bivalves (200 to 500 per square meter), abundant polychaetes, and abundant brittle stars (100 to 700 per square meter). Another study of this area reported 5,314 benthic organisms per square meter, comprising 41% polychaetes, 23% ophiuroids, 19% bivalves, 5.5% coelentera, and 3.4% crustaceans (Sanders, Hessler and Hampson, 1965). The silt-clay fauna is thus important for supporting populations of groundfish as well as migrating continental shelf edge lobsters (Pratt, 1973).

9.3. Biomass

Benthic productivity is important in maintaining the food chain of the ocean. In fact, the term "fish-food biomass" means the organic biomass in sediments available for fish to feed upon. The higher this number, the more food is available for bottom-feeding fish (Pratt, 1973). Benthic productivity is measured by biomass per unit area (grams of organism tissue per meter squared) and by the numbers of individuals per unit area. In the New England shelf area, biomass and population density both tend to decrease as water depth increases. For example, on Georges Bank, benthic biomass is greatest in depths between 25 and 150 meters, while population density tends to be greatest at midshelf depths (50 to 99 meters depth). (Theroux and Grosslein, 1987).

Often a thin layer of fine-grained flocculent organic matter covers the sediment surface, derived from the settling remains of plankton, fecal pellets, animals and plants living in the water column above. This results in a sediment that typically has more organic matter (2%) than sand (1% or less), and hence has greater food value. For example, Wigley and McIntyre (1964) sampled the benthic fauna off southern New England at depths of 40 to 58 meters, and reported an average dry weight concentration of amphipods in sediment of 2-6 g/m^2 dry weight (reported in Pratt, 1973). Closer to shore, Lee (1944) measured dry weight of all benthic organisms at 4.6 g/m^2, and the concentration of fish food organisms (excluding large bivalves and echinoderms) was 2.3 g/m^2.

Lee (1944) described a quantitative survey of fishing areas in Menemsha Bight off Martha's Vineyard and reported that sandy areas had lower fish-food biomass than silty-sand areas, less than 1 g/m^2 dry weight. However, Wigley (1965) shows a dry weight biomass of greater than 10 g/m^2 in stable sand areas surrounding Nantucket Shoals (Pratt, 1973). Butterfish, scup and summer flounder remain in areas of sandy bottom in the Mid-Atlantic Bight through much of the year (Pratt, 1973).

9.4. Biogeography

In terms of biogeography, the science of the geography of organisms, the offshore region between Cape Hatteras and Georges Bank, from 35 degrees N to about 42 degrees N, is complex and consists of a mixture of warm-water and cold-water species, as well as a number of species endemic to the area. Historically this region has been placed in any one of three benthic faunal provinces, described by Hazel (1970) and reviewed in Theroux and Grosslein (1987):

- A separate province, often called the Virginian Province, with a mild-temperate fauna, lying between a cold-temperate province to the north of Cape Cod (Nova Scotian or Boreal province), and a warm-temperate province (Carolinian) south of Cape Hatteras;
- An area of overlap or transition with a mixture of cold-temperate and warm-temperate fauna, not unique to the region, lying between the Nova Scotian and Carolinian provinces.
- A cold-temperate Boreal Province extending all the way from Cape Cod and Georges Bank to Cape Hatteras (south of which is the warm-temperate Carolinian province).

Different studies support one or another of these zoogeographic provinces, and are summarized in Theroux and Grosslein (1987) and below.

1) Separate province (Virginian province) lying between warmer southern and colder northern provinces

Hall (1964) studied mollusk distributions relative to temperatures required for successful reproduction, and concluded that the Cape Cod/Cape Hatteras region belonged in a separate Virginian province. Hazel (1970) studying ostracodes also concluded that this region was distinct, noting that the warm summer/fall temperatures off Cape Cod, the depth of the Northeast Channel and the high summer temperatures on Georges Bank were all barriers to the southward extension of many cold-water northern species, and similarly that a number of warm-water species reached their northern limit on eastern Georges Bank or off Cape Cod. Briggs (1974) felt that the entire region from Cape Hatteras to the Strait of Belle Isle should be a separate province, the Western Atlantic Boreal Zoogeographic region, based on the criteria of 10% endemism for province status. Watling (1979) showed that 18% of amphipods found from Cape Hatteras to Georges Bank were endemic, thus supporting the Virginian province (reviewed in Theroux and Grosslein, 1987).

2) An area of overlap, mixing, or transition between southern and northern fauna

Stephenson and Stephenson (1954) studied intertidal biota from Cape Cod to Cape Hatteras and concluded that the fauna represented a mixture of cold-temperate animals found north of Cape Cod and warm-temperate animals found south of Cape Hatteras. Kinner (1978) suggested that polychaetes in the Georges Bank-Cape Hatteras region fell into an overlap zone containing both northern and southern species. Bowen et al. (1979) studying benthic crustaceans in the Middle Atlantic Bight also came to this conclusion, finding that Cape Cod formed the northern range limit for numerous warm-water species of crustacea, although Cape Hatteras formed a more effective barrier for some species.

3) Southernmost limit of a cold-temperate Boreal province

Coomans (1962) studying mollusk distributions, decided that this region was mainly Boreal, since only about 10% of the species were endemic and most of the rest were of boreal (cold-water northern) origin. Most of the seastars and starfish in Georges Bank and the Gulf of Maine are related to boreal/subarctic groups, but some species reached their southern range limits along strong bottom-temperature gradients along the margins of Georges Bank and Nantucket Shoals (Franz, Worley and Merrill, 1981).

Theroux and Grosslein (1987) conclude that the benthic zoogeography of Georges Bank has yet to be definitively studied, that while most species are associated with cold-water fauna, there are significant southern associations, and that Georges Bank and nearby areas are clearly within a zone of rapid transition.

Scientists deploy a Bango-net on Georges Bank. NOAA Photo Library

9.5. Issues and Data Gaps

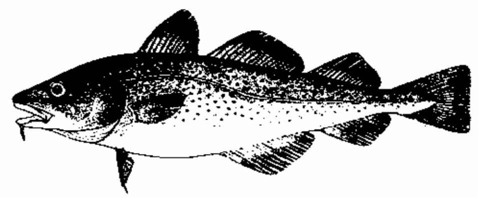
Because of the importance of benthic fauna in maintaining ocean productivity, and because of concerns about the state of the offshore fisheries in the Nantucket Shelf Region, the study of benthic fauna productivity, ecology, and taxonomy remains important. As climate changes, the physical factors that affect distributions and biomass of benthic fauna, such as water temperature, currents that affect sediment distributions, and primary productivity may change, thus affecting benthic fauna. Monitoring changes in benthic ecology and benthic fauna will continue to be important for understanding the overall ecology and living resources of the Nantucket Shelf Region.

Scientists recover a Chain-dredge on Georges Bank. NOAA Photo Library

Detailed mapping of benthic sediment characteristics and essential fish habitat should be done throughout the Nantucket Shelf Region, building on earlier studies of benthic fauna. Such information would provide a basis for better management of commercial and recreational fisheries in the region. The USGS has recently mapped sediment grain size off the northeast coast, including Nantucket Sound, Nantucket Shoals and the areas offshore of Cape Cod (Poppe and Polloni, 2000). This map provides a regional map of the sediment distribution in this area, and it provides an extremely useful tool for estimating where essential fish habitat may be located, based on extrapolation from other studies of Georges Bank and Stellwagen Bank. However, this mapping effort does not match the degree of detail achieved in high-resolution benthic mapping of Stellwagen Bank, for example.

The comprehensive approach used by USGS-NMFS, utilizing multisensor (sidescan and multibeam sonar, video photography, still photography, sediment sampling) to map and analyze benthic habitats should be applied to mapping Nantucket and Vineyard Sounds, Nantucket Shoals, the Great South Channel, and Georges Bank. The detailed information gained from such a comprehensive approach would provide resource managers with information needed to manage essential fish habitat and other important habitat.

10. FISH, FISHERIES AND SHELLFISH



Cape Cod forms a geographic boundary between the warm waters of the Mid-Atlantic Bight (Virginian zoogeographic province) and the colder waters of the Gulf of Maine (Acadian zoogeographic province), creating a transitional zone in Nantucket Sound and the adjacent shelf areas where warm and cold currents mix, and migratory species reach the extremes of their respective ranges (Ayvazian et al., 1992). This highly productive, dynamic environment sustains a diverse array of marine fish and invertebrate species that support commercial and recreational fisheries, contributing significantly to the economy of the region.

Since 1978, the Massachusetts Division of Marine Fisheries has conducted annual research cruises in spring and fall, utilizing a standardized otter trawl to assess population trends of demersal species. The database provides the most complete assessment of numbers and relative abundance of demersal species in Nantucket Sound during spring and fall. Although some fast-swimming pelagic species are not susceptible to the trawl gear, and a few species may be absent during the survey periods, it is the best long-term database available for Massachusetts Territorial Waters. During this period, over 100 species of fish and invertebrates have been captured, weighed and measured in Nantucket Sound.

Spring survey tows (Table 1) are characterized by adult fish, which migrate into Nantucket Sound for feeding and/or spawning purposes. Historically, the most numerous have been northern searobin (*Prionotus carolinus),* longfin squid* (*Loligo pealeii),* scup (*Stentomus chrysops),* windowpane flounder (*Scophthalmus aquosus),* winter flounder (*Pseudopleuronectes americanus),* Atlantic herring (*Clupea harengus*) juveniles, little skate (*Leucoraja erinacea),* butterfish (*Peprilus triacanthus),* winter skate (*Leucoraja ocellata*) and Atlantic cod (*Gadus morhua*) juveniles).

Fall survey tows (Table 2) include a larger number of species, characterized by many juvenile fish for which Nantucket Sound is a nursery area where temperature and available food promote rapid growth. Most numerous have been scup, longfin squid*, butterfish, black sea bass (*Centropristis striata*), bay anchovy (*Anchoa mitchilli*), striped anchovy (*Anchoa hepsetus*), northern searobin, little skate, smooth dogfish (*Mustelus canis*) and winter skate.

In addition to longfin squid, which is included with the finfish because of its similar life history characteristics, ecological importance and abundance, there are a number of invertebrate species that are susceptible to the survey gear, have been captured in great abundance, and are included here because of their importance in the demersal ecology. These include spider crabs (*Majidae* sp.), lady crab (*Ovalipes ocellatus*), Atlantic rock crab (*Cancer irroratus*), knobbed whelk (*Busycon carica*), and channeled whelk (*Busycotypus canaliculatis*).

A close examination of these data yields insights on the inter-specific relationships that make Nantucket Sound a productive marine ecosystem and important habitat for many species. By examining both weights and numbers of fish captured, the importance of the area as a nursery ground for a number of valuable commercial and recreational species is revealed (J. King, personal communication). The large number of juveniles, both those that are produced in the sound, like squid, and those that are produced outside the sound and migrate or drift in, like cod, thrive on benthic invertebrates and zooplankton in this productive environment, and grow to provide critical recruitment to these migratory populations. Some of the most numerous species, like anchovies, and the large numbers of juveniles of other species, like squid and scup,

Table 1. Spring catch at 522 Nantucket Sound stations.

	Spring Catch at 522 Nantucket Sound Stations MA Division of Marine Fisheries 1978 - 2003					
SVS	SCINAME	COMNAME	NUM	WT(kg)	NUMSTA	S
171	PRIONOTUS CAROLINUS	NORTHERN SEAROBIN	126,955	23,354.8	367	S
23	LEUCORAJA OCELLATA	WINTER SKATE	5,602	7,578.5	360	S
108	SCOPHTHALMUS AQUOSUS	WINDOWPANE	21,301	6,202.4	425	S
143	STENOTOMUS CHRYSOPS	SCUP	30,843	5,310.2	252	S
317	MAJIDAE	SPIDER CRAB UNCL	47,363	5,146.9	455	S
106	PSEUDOPLEURONECTES AMERICANUS	WINTER FLOUNDER	14,799	4,555.8	459	S
26	LEUCORAJA ERINACEA	LITTLE SKATE	7,383	4,449.5	434	S
503	LOLIGO PEALEII	LONGFIN SQUID	52,298	3,913.6	473	S
177	TAUTOGA ONITIS	TAUTOG	1,054	1,794.4	147	S
13	MUSTELUS CANIS	SMOOTH DOGFISH	426	1,602.8	86	S
15	SQUALUS ACANTHIAS	SPINY DOGFISH	355	1,392.0	46	S
103	PARALICHTHYS DENTATUS	SUMMER FLOUNDER	876	752.0	290	S
313	CANCER IRRORATUS	ATLANTIC ROCK CRAB	7,119	702.6	359	S
141	CENTROPRISTIS STRIATA	BLACK SEA BASS	976	511.8	160	S
337	BUSYCON CARICA	KNOBBED WHELK	1,277	400.3	136	S
131	PEPRILUS TRIACANTHUS	BUTTERFISH	6,613	345.8	126	S
163	MYOXOCEPHALUS OCTODECEMSPINOSUS	LONGHORN SCULPIN	1,044	323.8	159	S
336	BUSYCOTYPUS CANALICULATUS	CHANNELED WHELK	1,392	320.6	291	S
318	LIMULUS POLYPHEMUS	HORSESHOE CRAB	227	287.5	112	S
322	OVALIPES OCELLATUS	LADY CRAB	2,766	230.5	252	S
139	MORONE SAXATILIS	STRIPED BASS	309	224.6	16	S
33	ALOSA PSEUDOHARENGUS	ALEWIFE	1,895	127.1	57	S
520	LOLIGO PEALEII EGG MOPS	LONGFIN SQUID EGG MOPS		90.1	21	S
301	HOMARUS AMERICANUS	AMERICAN LOBSTER	378	87.6	138	S
338	NATICIDAE	MOON SNAIL, SHARK EYE, AND BABY-EAR	1,020	80.2	119	S
172	PRIONOTUS EVOLANS	STRIPED SEAROBIN	132	48.6	38	S
164	HEMITRIPTERUS AMERICANUS	SEA RAVEN	84	42.6	58	S
104	PARALICHTHYS OBLONGUS	FOURSPOT FLOUNDER	166	39.0	76	S
121	SCOMBER SCOMBRUS	ATLANTIC MACKEREL	71	32.9	15	S
343	MYTILUS EDULIS	BLUE MUSSEL	770	23.3	11	S
197	LOPHIUS AMERICANUS	GOOSEFISH	1	23.1	1	S
72	MERLUCCIUS BILINEARIS	SILVER HAKE	197	22.7	62	S
32	CLUPEA HARENGUS	ATLANTIC HERRING	13,636	19.4	40	S
77	UROPHYCIS CHUSS	RED HAKE	149	15.6	65	S
135	POMATOMUS SALTATRIX	BLUEFISH	7	15.2	5	S
181	AMMODYTES DUBIUS	NORTHERN SAND LANCE	3,156	14.6	56	S
193	MACROZOARCES AMERICANUS	OCEAN POUT	9	13.7	4	S
73	GADUS MORHUA	ATLANTIC COD	4,754	9.9	262	S
402	ARGOPECTEN IRRADIANS	BAY SCALLOP	214	8.5	29	S
105	LIMANDA FERRUGINEA	YELLOWTAIL FLOUNDER	29	3.7	15	S
75	POLLACHIUS VIRENS	POLLOCK	1,942	3.4	72	S
34	ALOSA AESTIVALIS	BLUEBACK HERRING	70	3.2	9	S
36	BREVOORTIA TYRANNUS	ATLANTIC MENHADEN	6	2.6	6	S
35	ALOSA SAPIDISSIMA	AMERICAN SHAD	35	2.3	16	S
28	AMBLYRAJA RADIATA	THORNY SKATE	4	2.0	2	S
176	TAUTOGOLABRUS ADSPERSUS	CUNNER	253	1.8	86	S
403	SPISULA SOLIDISSIMA	ATLANTIC SURFCLAM	16	1.8	11	S
312	CANCER BOREALIS	JONAH CRAB	12	1.8	2	S
348	EUSPIRA HEROS	NORTHERN MOONSNAIL	13	1.5	5	S
76	UROPHYCIS TENUIS	WHITE HAKE	113	1.4	53	S
401	PLACOPECTEN MAGELLANICUS	SEA SCALLOP	14	0.9	9	S
409	ARCTICA ISLANDICA	OCEAN QUAHOG	2	0.9	2	S
78	UROPHYCIS REGIA	SPOTTED HAKE	33	0.7	21	S
180	PHOLIS GUNNELLUS	ROCK GUNNEL	95	0.7	42	S
314	CALLINECTES SAPIDUS	BLUE CRAB	4	0.7	4	S
185	OPSANUS TAU	OYSTER TOADFISH	1	0.6	1	S
413	MERCENARIA MERCENARIA	NORTHERN QUAHOG	1	0.6	1	S
116	SYNGNATHUS FUSCUS	NORTHERN PIPEFISH	192	0.5	36	S
146	MENTICIRRHUS SAXATILIS	NORTHERN KINGFISH	2	0.4	2	S
335	PAGUROIDEA	HERMIT CRAB UNCL	6	0.3	2	S
384	ANGUILLA ROSTRATA	AMERICAN EEL	1	0.3	1	S
117	ETROPUS MICROSTOMUS	SMALLMOUTH FLOUNDER	54	0.2	36	S
453	MICROGADUS TOMCOD	ATLANTIC TOMCOD	1	0.2	1	S
168	CYCLOPTERUS LUMPUS	LUMPFISH	4	0.2	4	S
83	ENCHELYOPUS CIMBRIUS	FOURBEARD ROCKLING	1	0.1	1	S
109	CITHARICHTHYS ARCTIFRONS	GULF STREAM FLOUNDER	18	0.1	12	S
330	CLYPEASTEROIDA	SAND DOLLAR UNCL	10	0.1	1	S
331	ECHINOIDEA	SEA URCHIN AND SAND DOLLAR UNCL	3	0.1	1	S
323	STOMATOPODA	MANTIS SHRIMP UNCL	6	0.1	5	S
166	MYOXOCEPHALUS AENAEUS	GRUBBY	56	0.1	13	S
2	PETROMYZON MARINUS	SEA LAMPREY	1	0.0	1	S
170	LIPARIS ATLANTICUS	ATLANTIC SEASNAIL	1	0.0	1	S
502	ILLEX ILLECEBROSUS	NORTHERN SHORTFIN SQUID	15	0.0	4	S
326	CARCINUS MAENAS	GREEN CRAB	1	0.0	1	S
182	LUMPENUS LUMPRETAEFORMIS	SNAKEBLENNY	1	0.0	1	S
43	ANCHOA MITCHILLI	BAY ANCHOVY	5	0.0	2	S
165	ASPIDOPHOROIDES MONOPTERYGIUS	ALLIGATORFISH	2	0.0	1	S
113	MENIDIA MENIDIA	ATLANTIC SILVERSIDE	5	0.0	2	S
74	MELANOGRAMMUS AEGLEFINUS	HADDOCK	5	0.0	2	S

Table 2. Fall survey catches at 516 stations in Nantucket Sound.

Fall survey catches at 516 stations in Nantucket Sound, 1978-2003, ordered by number

MA Division of Marine Fisheries, Resource Assessment Project

SVS	SCINAME	COMNAME	NUM	WT	NUMSTA	S
143	STENOTOMUS CHRYSOPS	SCUP	1,488,463	12,035.8	514	F
503	LOLIGO PEALEII	LONGFIN SQUID	225,431	1,907.7	514	F
131	PEPRILUS TRIACANTHUS	BUTTERFISH	214,318	2,118.0	473	F
141	CENTROPRISTIS STRIATA	BLACK SEA BASS	57,025	692.0	416	F
43	ANCHOA MITCHILLI	BAY ANCHOVY	28,129	30.9	44	F
322	OVALIPES OCELLATUS	LADY CRAB	23,434	1,127.2	365	F
44	ANCHOA HEPSETUS	STRIPED ANCHOVY	16,992	21.9	46	F
171	PRIONOTUS CAROLINUS	NORTHERN SEAROBIN	12,828	1,106.1	343	F
317	MAJIDAE	SPIDER CRAB UNCL	9,186	768.1	405	F
26	LEUCORAJA ERINACEA	LITTLE SKATE	6,137	3,565.2	313	F
13	MUSTELUS CANIS	SMOOTH DOGFISH	6,104	4,696.3	365	F
23	LEUCORAJA OCELLATA	WINTER SKATE	4,086	3,715.5	256	F
337	BUSYCON CARICA	KNOBBED WHELK	2,841	1,092.2	279	F
313	CANCER IRRORATUS	ATLANTIC ROCK CRAB	2,014	97.0	195	F
135	POMATOMUS SALTATRIX	BLUEFISH	1,535	130.8	119	F
103	PARALICHTHYS DENTATUS	SUMMER FLOUNDER	1,410	1,129.4	319	F
336	BUSYCOTYPUS CANALICULATUS	CHANNELED WHELK	1,357	356.5	245	F
106	PSEUDOPLEURONECTES AMERICANUS	WINTER FLOUNDER	1,085	111.0	127	F
117	ETROPUS MICROSTOMUS	SMALLMOUTH FLOUNDER	1,043	7.8	131	F
177	TAUTOGA ONITIS	TAUTOG	884	178.0	79	F
176	TAUTOGOLABRUS ADSPERSUS	CUNNER	848	7.2	54	F
132	SELENE SETAPINNIS	ATLANTIC MOONFISH	799	4.4	37	F
108	SCOPHTHALMUS AQUOSUS	WINDOWPANE	639	147.1	172	F
181	AMMODYTES DUBIUS	NORTHERN SAND LANCE	583	2.4	20	F
116	SYNGNATHUS FUSCUS	NORTHERN PIPEFISH	448	1.3	89	F
208	DECAPTERUS MACARELLUS	MACKEREL SCAD	414	4.7	79	F
402	ARGOPECTEN IRRADIANS	BAY SCALLOP	411	26.9	26	F
318	LIMULUS POLYPHEMUS	HORSESHOE CRAB	355	605.3	122	F
146	MENTICIRRHUS SAXATILIS	NORTHERN KINGFISH	221	20.7	83	F
172	PRIONOTUS EVOLANS	STRIPED SEAROBIN	220	55.9	90	F
109	CITHARICHTHYS ARCTIFRONS	GULF STREAM FLOUNDER	181	2.6	32	F
301	HOMARUS AMERICANUS	AMERICAN LOBSTER	171	65.1	51	F
196	SPHOEROIDES MACULATUS	NORTHERN PUFFER	142	2.9	61	F
72	MERLUCCIUS BILINEARIS	SILVER HAKE	140	1.1	23	F
32	CLUPEA HARENGUS	ATLANTIC HERRING	133	0.9	11	F
15	SQUALUS ACANTHIAS	SPINY DOGFISH	128	265.6	16	F
338	NATICIDAE	MOON SNAIL, SHARK EYE, AND BABY-EAR	120	13.3	43	F
134	PRIACANTHUS ARENATUS	BIGEYE	96	1.0	28	F
201	MONACANTHUS HISPIDUS	PLANEHEAD FILEFISH	93	1.5	46	F
180	PHOLIS GUNNELLUS	ROCK GUNNEL	72	0.4	11	F
120	FISTULARIA TABACARIA	BLUESPOTTED CORNETFISH	63	1.6	22	F
76	UROPHYCIS TENUIS	WHITE HAKE	61	1.9	13	F
343	MYTILUS EDULIS	BLUE MUSSEL	58	10.5	9	F
403	SPISULA SOLIDISSIMA	ATLANTIC SURFCLAM	58	5.7	14	F
104	PARALICHTHYS OBLONGUS	FOURSPOT FLOUNDER	56	3.5	39	F
212	TRACHURUS LATHAMI	ROUGH SCAD	54	1.8	9	F
556	PRIACANTHUS CRUENTATUS	GLASSEYE SNAPPER	36	0.7	3	F
439	TRACHINOCEPHALUS MYOPS	SNAKEFISH	36	0.3	6	F
166	MYOXOCEPHALUS AENAEUS	GRUBBY	32	0.1	5	F
77	UROPHYCIS CHUSS	RED HAKE	29	0.4	12	F
557	PRISTIGENYS ALTA	SHORT BIGEYE	28	0.7	9	F
342	MODIOLUS MODIOLUS	NORTHERN HORSEMUSSEL	27	2.3	4	F
34	ALOSA AESTIVALIS	BLUEBACK HERRING	22	0.8	5	F
36	BREVOORTIA TYRANNUS	ATLANTIC MENHADEN	21	0.5	5	F
187	MULLUS AURATUS	RED GOATFISH	19	0.3	7	F
78	UROPHYCIS REGIA	SPOTTED HAKE	18	2.2	6	F
330	CLYPEASTEROIDA	SAND DOLLAR UNCL	16	0.5	1	F
202	BALISTES CAPRISCUS	GRAY TRIGGERFISH	14	10.7	4	F
33	ALOSA PSEUDOHARENGUS	ALEWIFE	14	0.5	5	F
175	DACTYLOPTERUS VOLITANS	FLYING GURNARD	12	0.6	3	F
129	CARANX CRYSOS	BLUE RUNNER	11	0.4	8	F
832	ALUTERUS SCHOEPFI	ORANGE FILEFISH	11	0.3	7	F
435	SYNODUS FOETENS	INSHORE LIZARDFISH	9	0.5	7	F
662	CHAETODON OCELLATUS	SPOTFIN BUTTERFLYFISH	9	0.0	2	F
4	DASYATIS CENTROURA	ROUGHTAIL STINGRAY	8	714.2	7	F
314	CALLINECTES SAPIDUS	BLUE CRAB	6	0.9	6	F
209	SELAR CRUMENOPHTHALMUS	BIGEYE SCAD	6	0.1	4	F
694	SPHYRAENA BOREALIS	NORTHERN SENNET	5	0.0	3	F
384	ANGUILLA ROSTRATA	AMERICAN EEL	4	0.4	1	F
164	HEMITRIPTERUS AMERICANUS	SEA RAVEN	4	0.3	1	F
695	SPHYRAENA GUACHANCHO	GUAGUANCHE	4	0.2	4	F
305	CRUSTACEA SHRIMP	SHRIMP UNCL	4	0.1	1	F
537	EPINEPHELUS NIVEATUS	SNOWY GROUPER	4	0.0	4	F
323	STOMATOPODA	MANTIS SHRIMP UNCL	4	0.0	4	F
163	MYOXOCEPHALUS OCTODECEMSPINOSUS	LONGHORN SCULPIN	4	0.0	2	F
312	CANCER BOREALIS	JONAH CRAB	3	0.4	3	F
852	SYNODONTIDAE	LIZARDFISH UNCL	3	0.0	3	F
739	GOBIIDAE	GOBY UNCL	3	0.0	1	F
133	SELENE VOMER	LOOKDOWN	3	0.0	2	F
12	CARCHARIAS TAURUS	SAND TIGER	2	25.4	2	F
139	MORONE SAXATILIS	STRIPED BASS	2	10.4	2	F
149	LEIOSTOMUS XANTHURUS	SPOT	2	0.9	2	F
204	SERIOLA ZONATA	BANDED RUDDERFISH	2	0.4	2	F
83	ENCHELYOPUS CIMBRIUS	FOURBEARD ROCKLING	2	0.1	2	F
45	OSMERUS MORDAX	RAINBOW SMELT	2	0.0	1	F
489	FISTULARIA PETIMBA	RED CORNETFISH	2	0.0	2	F
568	ALECTIS CILIARIS	AFRICAN POMPANO	2	0.0	2	F
542	MYCTEROPERCA PHENAX	SCAMP	2	0.0	2	F
311	CANCRIDAE	CANCER CRAB UNCL	2	0.0	2	F
145	CYNOSCION REGALIS	WEAKFISH	1	2.6	1	F
409	ARCTICA ISLANDICA	OCEAN QUAHOG	1	0.6	1	F
185	OPSANUS TAU	OYSTER TOADFISH	1	0.2	1	F
541	MYCTEROPERCA MICROLEPIS	GAG	1	0.1	1	F
416	SOLENIDAE	RAZOR AND JACKKNIFE CLAM UNCL	1	0.1	1	F
118	TRINECTES MACULATUS	HOGCHOKER	1	0.1	1	F
840	LACTOPHRYS TRIGONUS	TRUNKFISH	1	0.0	1	F
833	ALUTERUS SCRIPTUS	SCRAWLED FILEFISH	1	0.0	1	F
569	CARANX BARTHOLOMAEI	YELLOW JACK	1	0.0	1	F
531	EPINEPHELUS ADSCENSIONIS	ROCK HIND	1	0.0	1	F
328	CALAPPA FLAMMEA	FLAME BOX CRAB	1	0.0	1	F
63	CONGER OCEANICUS	CONGER EEL	1	0.0	1	F
520	LOLIGO PEALEII EGG MOPS	LONGFIN SQUID EGG MOPS		2.1	10	F

NUMSTA = NO.STATIONS SPECIES PRESENT S = SEASON

are forage for migratory predators that seasonally enter the sound to feed when conditions are favorable. These species, including striped bass, summer flounder, bluefish, Spanish mackerel, bonito and false albacore depend on the concentration of abundant prey species on shoals and sand waves as a critical part of their life histories, sustaining seasonal growth and increasing reproductive potential. The role of Nantucket Sound as a spawning/nursery area and seasonal feeding area qualifies it as essential fish habitat for most of the species listed above. The concentration of predators and prey on shoal areas and other bottom features creates fishing opportunities for commercial and recreational fishermen.

The estuaries along the south shore of Cape Cod represent a different habitat for a similar suite of species. Curley et al. (1971) and (1975) listed a total of 40 finfish species in Waquoit Bay, and 43 species in Bass River (Tables 3 and 4, respectively). The important role of these estuaries in providing nursery areas and primary productivity, contributing to the ecology of Nantucket Sound, cannot be overemphasized.

Table 3. ***Relative Abundance of All Species Taken at Seven Finfish Sampling Stations in Waquoit Bay, 1967–1968.***

Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.*[1]	Feb.*[2]	Mar.	Apr.	May	Total
Tidewater silverside	597	187	674	671	1,561	2,290	107			812	19	944	7,862
Mummichog	1,273	1,057	817	2,250	1,147	9	16			8	47	524	7,148
Atlantic silverside	656	60	1,320	724	198	33	134			30	95	240	3,490
Striped killifish	43	16	227	201	353	96	10			10	9	58	1,023
Fourspine stickleback	420	131	79	47	30	30	14			38	37	14	840
Winter flounder	27	76	52	78	40	15	7			10	45	49	399
Northern pipefish	146	31	73	15	16	11	2			1	6	7	308
Cunner	18	18	44	36	32	8				2	6	35	199
Sheepshead minnow	4		32	53	64	9	7						169
Threespine stickleback	15	4	30		16	6	8			8	30	14	131
Rainwater killifish	12	47	22	22	19	5	L						128
Atlantic menhaden				116	3	1							120
Tautog	9	21	39	24	10	1				1		5	110
American eel	25	50	8	2		4					2	9	100
Alewife			71	2	8	1						1	83
Atlantic tomcod	23	26	12	1	1		1				3	9	76
Northern puffer			47	2									49
Scup			23	5	13								41
Grubby	11	1	3		2	3	9			1	8	2	40
White hake	15	6	9	4	2								36
Oyster toadfish	5	2	5	3	1						5	15	36
Pollock	1										15	2	18
American sand lance	3	2			1	2					1	1	10
Rainbow smelt			3	1	1					1	1	2	9
Atlantic needlefish		1	3	1									5
Blueback herring			4										4
Northern searobin			1	3									4
Rock gunnel	3	1											4
Summer flounder		2	2										4
Atlantic cod	2												2
Bluefish				2									2
Ninespine stickleback			1									1	2
Black seabass					1								1
Golden shiner			1										1
Longhorn sculpin						1							1
Lumpfish							1						1
Striped bass					1								1
Striped mullet					1								1
Striped searobin			1										1
Blackspotted stickleback											1		1

- [1] No sampling was conducted in January due to ice.
- [2] Only Station 4 (East Flat) was sampled in February.

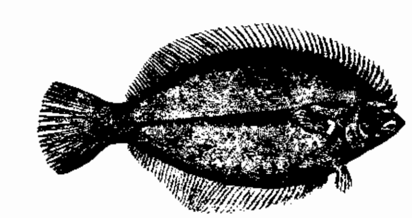


Table 4. *Numerical Rank of Finfish Species Taken in Bass River During Monthly Beach Seine Sampling, 1970-1971*

	1970			1971											
	10/5	11/3	12/3	1/12	3/16	4/6	4/21	5/5	6/7	7/1	7/23	8/2	8/18	9/16	Total
Atlantic silverside	907	403	357		398	57	1246	348	70	4110	3125	2069	3499	3283	19,872
tidewater silverside	3432	4087	596		15	11	2	55	186	1441		350		1	10,176
mummichog	507	962	315		17	9	8	44	561	854	755	3558	1979	6	9,575
striped killifish	527	265	275			1	1	3	105	618	1120	1991	1464	39	6,409
fourspine stickleback	160	384	54		34	9	1	124	95	23	1	184	10	7	1,086
Atlantic menhaden												600			600
American sand lance			5		494	5		1							505
Atlantic herring							160								160
northern puffer											4	116	21	1	142
Atlantic needlefish	4									14	10	27	44	36	135
northern pipefish	36	1				1			6	10	4	35	3	1	97
striped mullet									1			8	21	56	86
crevalle jack												2	19	58	79
winter flounder	6	6	9		1		1		1	13	2	8	2	8	57
sheepshead minnow	18	3	1									1	18		41
scup														36	36
alewife			6							14	4	2		7	33
American eel	2				1			1	1	13		11	1	2	32
striped searobin										1	7	12	5	1	26
threespine stickleback		1				1	1	14	6						23
black sea bass	16														16
oyster toadfish	1											3		3	7
rainwater killifish	2	1												1	4
blue runner												3			3
bluefish	2											1			3
Atlantic tomcod															2
blueback herring	1							2			1				2
northern kingfish												1			1
tautog												1			1

	1970			1971										
	10/13	11/10	12/15	2/23	3/9	4/8	5/11	6/8	7/6	8/6	8/18	8/18*	9/23	Total
fourspine stickleback			4		17	18	2	60	6		35	6	59	207
winter flounder	1			1	3	9	20	6	3	1	8	10	1	63
black sea bass											31	11	11	53
oyster toadfish							12	5	6	1	7	3	2	37
tautog							1			1	1	2	32	36
American eel							1	15	12	3	3		2	36
scup												17	18	35
mummichog											4	20	3	27
northern pipefish								2		3	4	4	2	15
Atlantic tomcod					1		2	6	1			1	2	13
Atlantic menhaden										1		7		8
tidewater silverside			6								2			8
common searobin									3		2	2		7
cunner											1	1	3	5
alewife						2							1	3
hogchoker								1	1			1		3
Atlantic silverside										1			1	2
orange filefish												1	1	2
smooth dogfish												2		2
lookdown										1				1
northern puffer													1	1
planehead filefish												1		1
striped bass												1		1
striped searobin											1			1
threespine stickleback						1								1

*Supplementary night sampling

10.1. Commercial Fisheries

Cod fishermen early 1900s. photo: NOAA library

Nantucket Sound has historically supported a variety of important commercial fisheries for finfish and invertebrate species that have contributed to the local character and economy since the colonial era. Traditional methods, which in some cases predate the earliest European settlement, are commonly used in the area.

Fish weirs, which consist of netting hung on wooden poles driven into the bottom, with a long leader guiding fish into a heart-shaped trap, are one of the oldest forms of passive fishing, still practiced on the shoals west of Monomoy Island, in the eastern end of the sound and along the south shore of Cape Cod. Schooling fish typically encounter the leader as they follow the shoreline, and swim into the trap. Landings in recent years have included Atlantic, king, and Spanish mackerel, squid, scup, butterfish, and bluefish, and have exceeded a million pounds in recent years (Division of Marine Fisheries).

Hooks on baited longlines, rod and reel, or handlines are used by a large fleet of small dayboats fishing from Chatham, Harwich, and other Cape and Islands Towns. Cod are targeted during early spring and late fall on Nantucket Shoals and the Great South Channel and east of Cape Cod, and some boats travel farther offshore to fish for haddock. Some of these boats switch to bluefin tuna and striped bass during the summer and early fall to take advantage of the migrations of these high-value species. Other species commonly landed by hook and line include pollock, bluefish, summer flounder, scup and black sea bass. Harpoons are also used to take bluefin tuna east of Cape Cod. Gillnets, although not allowed in Nantucket Sound or in state waters to the south, are fished by a number of Chatham vessels east of Cape Cod.

Fishing on the Bank. photo: NOAA library

A variety of baited pots and traps hauled to the surface are used to fish for lobster, black sea bass, scup, and conchs. Although few lobster pots are fished inside the sound, lobster vessels from Cape and Islands ports fish at the extreme eastern and western ends, in Vineyard Sound and south of the Islands. Black sea bass and conch are potted throughout the sound. A total of 35 vessels fished black sea bass pots in 2000, and landed a reported 625,902 pounds. In the same year, 39 conch potters reported landings of 1,078,956 pounds (Division of Marine Fisheries).

Larger vessels towing otter trawls fish seasonally in the sound as quotas and regulations allow. They fish mainly for squid, flounders (summer flounder, winter flounder, and windowpane), scup, conchs and horseshoe crabs. Landings by trawlers in 2000 included 637,522 pounds of squid and 508,785 pounds of summer flounder, most from Nantucket and Vineyard Sounds (Division of Marine Fisheries). South and east of Cape Cod these vessels also pursue groundfish, including cod, haddock, and yellowtail flounder.

Commercial fishing for migratory species found south of Cape Cod is subject to fisheries management plans developed outside Massachusetts, either by the Atlantic States Marine Fisheries Commission or the Mid-Atlantic Fisheries Management Council, and most species are subject to strict quotas. Although the center of Nantucket Sound beyond three miles from shore is Federal water (Exclusive Economic Zone), it falls under the fisheries management authority of the Commonwealth, and is subject to regulations of the Division of Marine Fisheries. Commercial landings from lower Cape Cod ports (Provincetown – Chatham) totaled 15.4 million pounds worth 15.2 million dollars. (NOAA Fisheries). A large percentage of these landings are from the Nantucket Shelf and the Great South Channel.

10.2. Recreational Fisheries

Although it is difficult to separate the number of Nantucket Sound anglers from the rest of the Massachusetts coastline, they surely number in the hundreds of thousands. Statewide, about 800,000 marine anglers generate nearly a billion dollars in annual economic activity, and Nantucket Sound is one of the most popular fishing areas. From early spring to late fall a succession of migratory species are available to local anglers and tourists. In early spring, winter flounder and white perch are found in the estuaries. Spring brings tautog, scup and black sea bass, along with the premier sport fish, striped bass. Late spring brings bluefish and summer flounder.

More exotic species like bonito, false albacore and Spanish mackerel arrive in mid-summer and stay through early fall when the warmest water temperatures occur. South of the Islands, at the edge of the shelf, offshore sportfishing vessels fish for large oceanic pelagic species, such as blue marlin, white marlin, swordfish, bluefin tuna, yellowfin tuna, blue shark and mako shark. Fishing occurs from shore and from large numbers of private vessels. Approximately 150 charter and party vessels are available for hire, making it easy for visitors to access productive fishing areas. The close association with tourism makes recreational fishing one of the most important activities contributing to the economy of Cape Cod and the Islands.

10.3. Anadromous Fish

Most of the rivers and large streams entering Nantucket Sound from Cape Cod and the Islands provide spawning habitat or access to freshwater ponds for spawning by river herring. Blueback herring spawn in the rivers, while alewives ascend the rivers to freshwater ponds to spawn. River herring are an important component of the forage base, providing food for striped bass and other large predators during the spawning run and when spent fish return to the Sound. During fall, large schools of juvenile herring migrating from fresh to salt water are preyed upon by a wide variety of fish and avian predators, forming an important component of the forage base. Figure 24 shows the location of anadromous fish runs and fish passage facilities bordering Nantucket Sound.

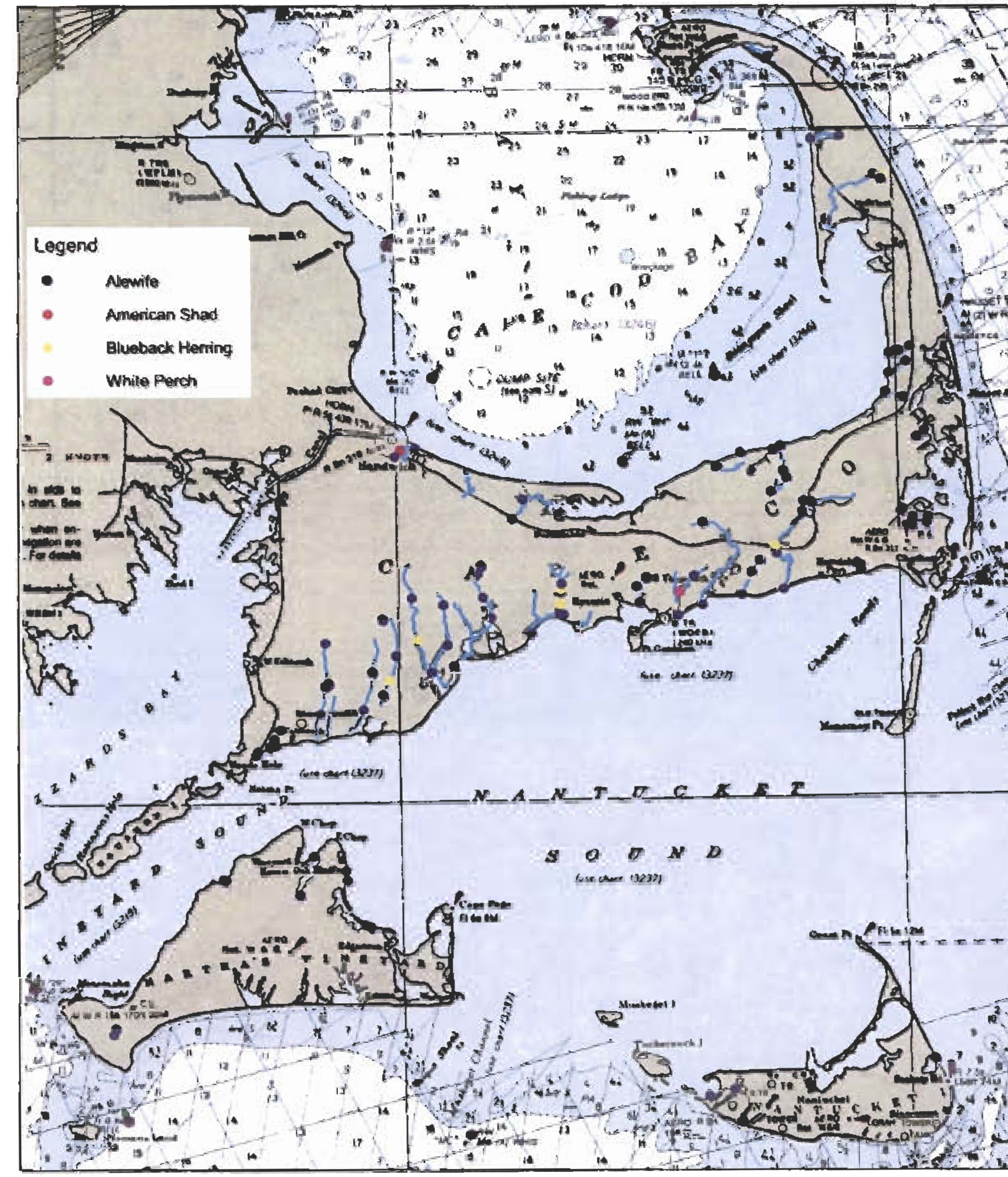


Figure 24. Anadromous Fish Runs. Data from MASSGIS, map Horsley Witten Group.

10.4. Catadromous Fish

Most of the rivers and streams in the area are inhabited by American eels. The entire population of this species spawns in the Sargasso Sea area of the South Atlantic. Larvae drift north in the Gulf Stream and eventually reach the shoreline. Since they have no control over where they reach landfall, they are assumed to ascend the nearest freshwater stream and morph into elvers, then juvenile eels. They may live for many years in fresh water before making the return journey to spawn, while some stay in the brackish estuaries. The adults are trapped commercially and are valued as food by certain ethnic groups, while the juveniles are prized as bait for striped bass.

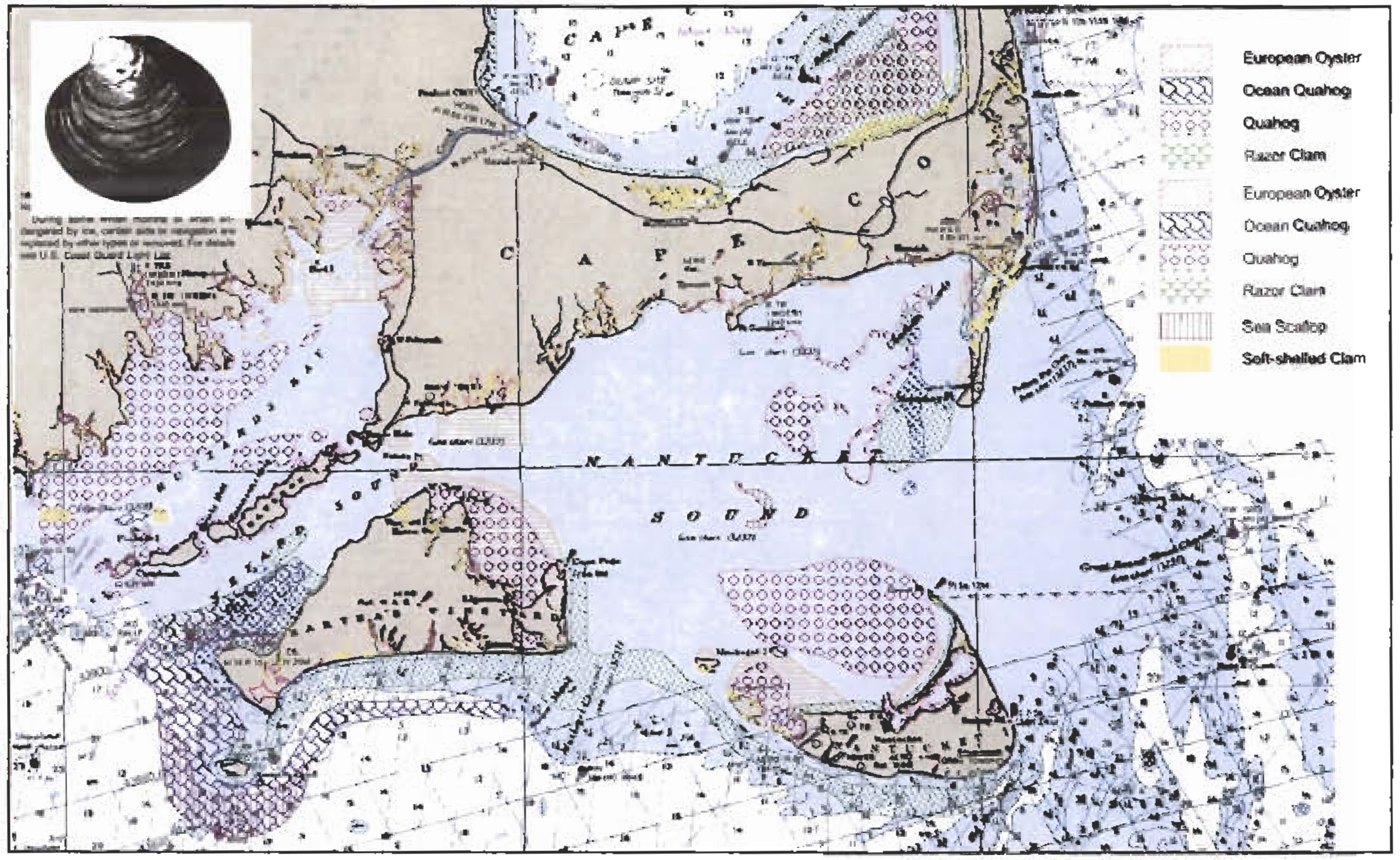


Figure 25. Suitable Shellfish Habitat Map. Data from MASSGIS, map Horsley Witten Group.

10.5. Shellfish

In Massachusetts, coastal towns have primary management authority over shellfish resources within their boundaries. Each of the towns bordering the sound has a variety of shellfish species that provide a source of employment and recreation. These include the hard clam or quahog, soft-shelled clam, blue mussel, American oyster, and bay scallop. Also under town control with state oversight are a number of private aquaculture operations raising shellfish in controlled culture. A total of 31 sites in the estuaries bordering the sound are licensed to aquaculturists raising quahogs and oysters (Moles, 2002). Offshore, there are state-managed species such as surf clam and ocean quahog, which are harvested by large dredge vessels around and south of the Islands. There are also offshore populations of bay quahog in the eastern end of the sound and on the shoals that are harvested by dredge boats. Just outside state waters on the shelf east of Chatham and Nantucket there are vessels dredging for sea scallop and blue mussel. Figure 25 shows the mapped areas of known shellfish habitat in nearshore areas of the Nantucket Shelf area (from MassGIS).

10.6. Issues and Data Gaps

Rapid development of the coastal zone of the Cape and Islands has created challenges for shellfish managers, including greatly increased numbers of recreational and commercial harvesters and increased non-point contamination of growing waters. From 1990 to 2002, Cape Cod's population grew 21% to nearly 250,000 year-round residents (Cape Cod Times, 7/27/04). Thanks to aggressive local, regional and state programs to abate non-point pollution, most areas are still suitable for shellfishing, at least on a seasonal basis, and DMF programs to monitor bacterial contamination and paralytic shellfish poison ensure that the public can continue to safely enjoy the benefits of safe shellfish resources.

Given the rich and abundant fisheries and fishing activities that exist in Vineyard and Nantucket Sounds, it is surprising that no systematic in-depth benthic habitat surveys, like those conducted by the USGS and NMFS for Stellwagen Bank and Georges Bank, have ever been conducted in these areas, for the purpose of assessing the condition of the benthic habitat and informing coastal fisheries managers. The lack of such studies is a serious and significant information gap that should be addressed by coastal managers seeking to restore essential fish habitat.

The importance of nursery habitat needs to be understood thoroughly. In a recent review of the science of nursery habitats in marine and coastal ecosystems, a panel of scientists concluded that, although the concept of nursery habitat has been used by resource managers, nursery habitat has not been clearly defined and therefore identification of valuable nursery habitat has been hindered (Beck et al., 2003). The best measure of nursery habitat value may be tracking the number of individuals that move from juvenile to adult habitats, while the best single measure of the value of juvenile habitats is the total biomass of individuals added to adult populations.


Shellfisherman. photo: NOAA archive

11. MARINE MAMMALS

11.1. Marine Mammal Occurrences

In the Nantucket Shelf region, the Great South Channel, Stellwagen Bank and Georges Bank are the premier areas for congregation, feeding and passage of marine mammals, including seals,right whales, humpback whales, fin whales, and Atlantic white-sided dolphins (Figures 26, 27). Sharks and pelagic and demersal fish and seabirds also are attracted to this area because of the copepod blooms that occur in spring.

Few whales enter Nantucket or Vineyard Sound, although some have been observed over the years (Pilson and Goldstein, 1973). Smaller marine mammals such as seals and dolphins do enter the Sounds.

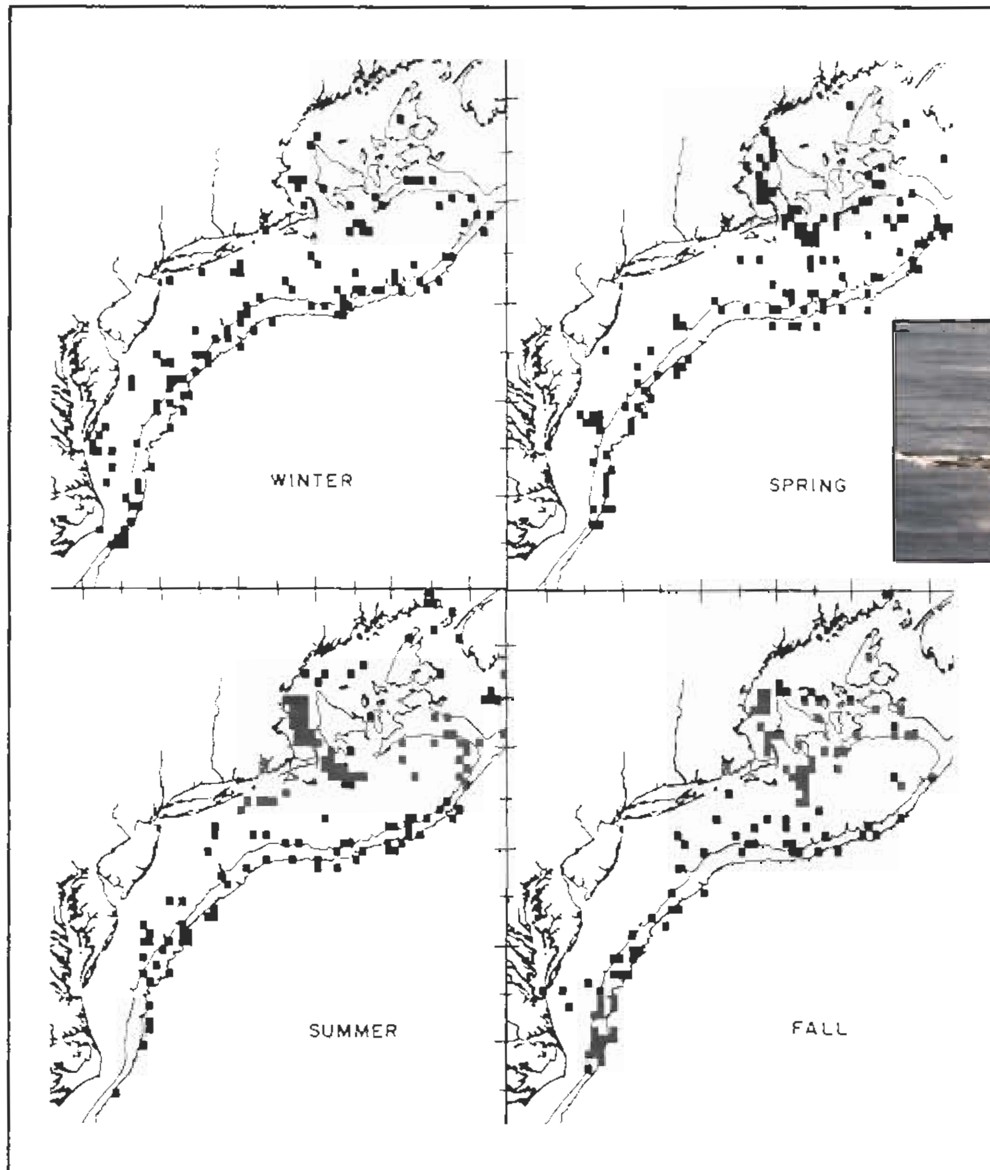


Figure 26. Seasonal patterns of the top 10% of total cetacean biomass per unit effort values. Kenney and Winn (1986).

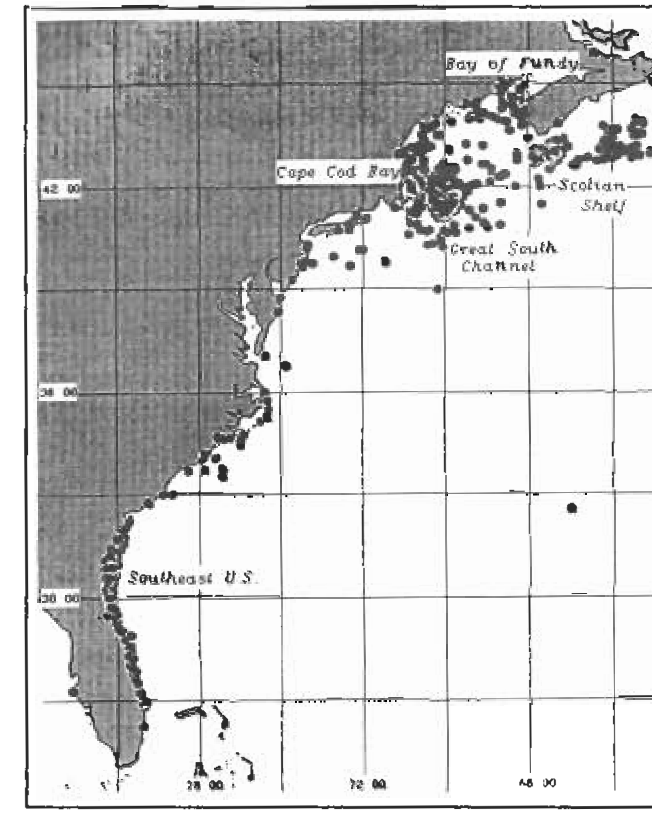


Figure 27. Distribution of sightings of right whales (*Eubalaena glacialis*) in the western North Atlantic, identifying the five primary habitats which are currently known. Kenney et al. (1995).

In the area between Cape Cod and Cape Hatteras, the following marine mammals are found (Pilson and Goldstein, 1973) (Table 5). Food preferences are noted.

Table 5. Marine Mammals Occurring Between Cape Cod and Cape Hatteras (Pilson and Goldstein, 1973).

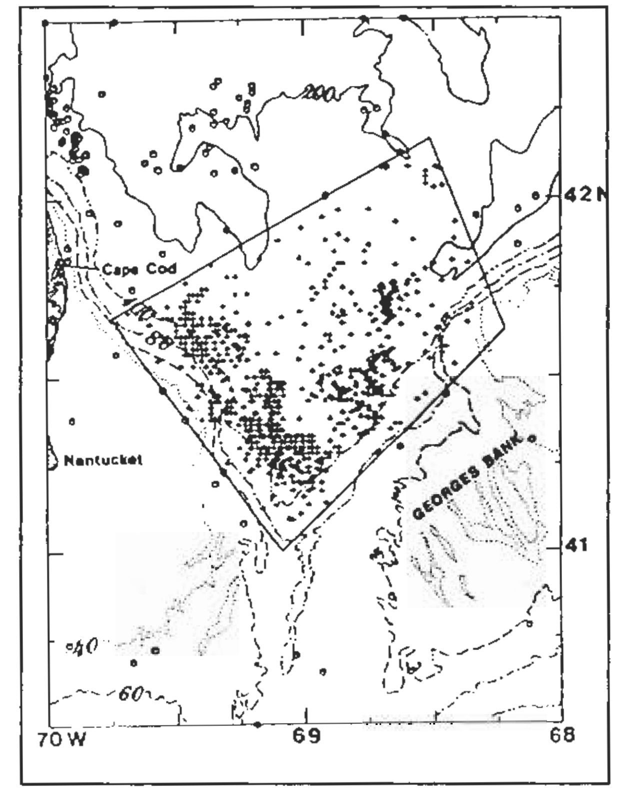
Family	Genus and Species	Common name	Food
Odobenidae	*Odobenus rosmarus*	Walrus	Clams
Phocidae	*Phoca vitulina*	Common (Harbor) seal	Fish
	Halichoerus grypus	Gray seal	Fish, squid
	Pagophilus groenlandicus	Harp seal	
	Cystophora cristata	Hooded seal	Fish, squid, shrimp, mussels, starfish
Balaenidae	*Balaena glacialis*	Right whale - Endangered	Planktonic crustaceans (e.g., copepods, others)
Balaenopteridae	*Balaenoptera acutorostrata*	Minke whale	Fish (esp. herring)
	Balaenoptera borealis	Sei whale - Endangered	Plankton (e.g., copepods)
	Balaenoptera physalus	Fin whale - Endangered	Pelagic crustaceans (e.g., euphausiids), capelin, and herring
	Balaenoptera musculus	Blue whale (Gulf of Maine) - Endangered	Plankton and krill
	Megaptera novaeangliae	Humpback whale - Endangered	Krill, capelin, sand lance, and herring-sized fish

(**Table 5.** continued) Marine Mammals Occurring Between Cape Cod and Cape Hatteras

(Pilson and Goldstein, 1973).

Delphinidae	*Tursiops truncatus*	Bottle-nosed dolphin	Fish, birds, sea lettuce (*Ulva*), other
	Grampus griseus	Grampus or Risso's dolphin	Squid
	Lagenorhynchus albirostris	White-beaked dolphin	Whiting, whelk, capelin, cod, squid, hermit crabs, other crustaceans
	Lagenorhynchus acutus	White-sided dolphin	Herring and squid
	Stenella dubia	Spotted dolphin	Fish and cephalopods (e.g., squid, octopus)
	Delphinus delphis	Common dolphin	Fish
	Pseudorca crassidens	False killer whale	Squid, octopus, fish
	Globicephela melaena	Pilot whale	Squid, cod
	Globicephala macrorhyncha	Short-finned pilot whale	Squid, cod
	Orcinus orca	Killer whale	Seals, porpoises, sea otters, birds, fish, squid, octopus, leatherback turtles
	Phocoena phocoena	Harbor porpoise	Pilchard, herring, mackerel, whiting, hake, pollock
Monodontidae	*Delphinapterus leucas*	Beluga or white whale	Anadromous fish, squid, bottom-living fish, invertebrates
Physeteridae	*Physeter catodon*	Sperm whale	Squid, octopus, halibut, bottom fish, sharks
	Kogia breviceps	Pygmy sperm whale	Squid, crabs, shrimp
	Kogia simus	Dwarf sperm whale	Squid, crabs, shrimp?
Ziphiidae	*Mesoplodon bidens*	North Sea beaked whale	Squid?
	Mesoplodon mirus	True's beaked whale	Squid, octopus, occasionally fish
	Mesoplodon densirostris	Dense-beaked whale	No information
	Ziphius cavirostris	Goose-beaked whale	Cuttlefish and squid?
	Hyperoodon ampullatus	North Atlantic bottle-nosed whale	Squid, occasionally herring and other fish

From this list, it is apparent that the marine mammals found in this region are either carnivorous or planktivorous; that is, none feed upon vegetation solely. This is probably related to their caloric needs to sustain their large body masses. For example, a Right Whale needs a food density of 7.57 to 2,395 kilocalories per cubic meter (1 kilocalorie = 1 dietary calorie for humans) in order to maintain itself (Kenney et al., 1986). This energy requirement is believed to drive the Right Whale to seek out areas of the ocean where their favorite food is highly concentrated, much as humans seek out supermarkets.
This concentration of food required is about 1 to 3 orders of magnitude greater than the highest concentrations of calories found in the Great South Channel, an area where the spring bloom of a particular species of copepod, *Calanus finmarchicus*, provides such a nutritional boost, attracting Right Whales to congregate here in high densities (Kenney and Wishner, 1994; Kenney et al., 1994; Kenney et al., 1986). Figure 28 shows all right whale sightings in the Great South Channel between 1975 and 1989 (National Marine Fisheries, 1991).



Right Whale flukes. photo: NOAA photo library

Figure 28. All right whale sightings in and near the proposed Great South Channel critical habitat between 1975 and 1989. Sightings within the proposed critical habitat are shown by + symbols; sightings outside by "o". bathymetry shown in meters. N = 942 sightings.
From National Marine Fisheries Service (1991).

Right whales must therefore have to be efficient in collecting their food, given that the optimum food concentration occurs only occasionally. The Right whale is also unusual in that it is an apex predator, yet feeds low on the food chain, on copepods, in particular *Calanus finmarchicus* (Kenney and Wishner, 1995). Only several hundred Right whales exist in the western North Atlantic population, and together with the Southern hemisphere population, they are the most endangered large whale species in the world. Aside from hunting, the lack of dense food sources in the ocean may account for their failure to recover as a species (Kenney et al., 1995).

The nutrient processes that sustain the growth of phytoplankton that *Calanus* feeds upon are not well understood. In a program to study the physical oceanography, biology, and chemistry of the Great South Channel, called the South Channel Ocean Productivity Experiment (SCOPEX), Kenney and Wishner (1995) cited three possible mechanisms for the high concentrations of *Calanus* and other zooplankton in the Great South Channel:

Hypothesis 1: The *in situ* productivity hypothesis. There is an increase in primary productivity because of added nutrients from upwelling and/or mixing in the Great South Channel, and a transfer of energy up the food chain, resulting in increased zooplankton abundance.

Hypothesis 2: The advection hypothesis. There is a continuous advection of zooplankton from source regions outside the Great South Channel into the Great South Channel, where the hydrographic features (e.g., circulation patterns, tides, basin geometry, ec.) result in a concentration of zooplankton. The concentration mechanisms may involve an interaction between the oriented swimming behavior of the zooplankton and the regional hydrography.

Hypothesis 3: The behavior hypothesis. There is a behavioral (possibly ontogenetic) tendency to form dense patches ("swarming"). This would not necessarily require any overall increase in average water column abundances in zooplankton.

The SCOPEX studies did not provide evidence for localized upwelling that would bring nutrient-rich water to the surface to enhance primary productivity, and Kenney and Wishner concluded that the *in situ* productivity hypothesis could be ruled out. Copepods do appear to be carried into the area in a southward-flowing low salinity plume on the western side of the Great South Channel. This suggests that the advection hypothesis may be true. The behavior hypothesis was partially addressed during the SCOPEX experiments (Durbin et al., 1995), although this study focused on vertical rather than lateral migration.

Even less understood is the role of the Nantucket Shelf region, and in particular Nantucket Sound and Nantucket Shoals, in nutrient cycling and dynamics. The Nantucket Sound and Nantucket Shoals regions are very well mixed due to the strong tides, currents and winds in this area. In fact, there is a distinct boundary between the well-mixed Nantucket Shoals water and the water flowing through the Great South Channel. This boundary, or "mixing front", is located approximately 10 km east of Nantucket Shoals (Chen et al., 1994a, 1994b). This mixing front located east of Nantucket Shoals is significant for ecosystem dynamics because it represents a place where the well-mixed water of the Sound and Shoals, carrying nutrients, salt, and any pollutants from human activities on land, feeds into the more stratified or layered waters of the Great South Channel.

11.2. Issues and Data Gaps

Little or no information is available concerning nutrients in Vineyard Sound, Nantucket Sound and Nantucket Shoals, and how such nutrients may affect offshore shelf ecosystems. Available data concerning nutrient loading come from studies of coastal embayments along Cape Cod. These data indicate that developed coastal embayments are generally suffering from nutrient loading. Once nutrients and other pollutants enter Nantucket Sound or Vineyard Sound, however, they are generally assumed to be diluted by rapid mixing. One major question is how much nutrient loading Nantucket Sound or Nantucket Shoals could accommodate before beginning to show signs of ecological stress. This question has not been addressed for Nantucket Sound or Nantucket Shoals. The impact upon marine mammals has yet to be studied.

It is clear that marine mammals depend upon fish, shellfish and other invertebrates for their food, and that the collapse of marine fisheries and damage to benthic habitats must therefore affect marine mammal populations. There are no studies of benthic habitat, prey densities and marine mammal ecology for Nantucket or Vineyard Sounds or Nantucket Shoals. Such studies have been conducted on Georges Bank and in the Gulf of Maine for humpback whales and fin whales and one of their important prey species, sand lance (*Ammodytes americanus*) (Payne et al., 1985; Meyer et al., 1979). In order to help restore these populations, which include endangered species, a holistic ecosystem restoration must take place which includes restoration of benthic habitat for invertebrates and restoration of fish populations.

If the Nantucket Shelf region serves an important role in fisheries and benthic habitat (as is indicated by the fisheries activities), then we may hypothesize a "spillover effect" of prey populations that spread into adjacent shelf regions via the rapid currents; this remains to be tested, however. This hypothesis is like the "advection hypothesis" posed by Kenney and Wishner (1995) to explain why copepods are abundant in the Great South Channel; they appear to be carried in, or advected into, the Great South Channel, where they proceed to mature.

12. BIRDS

photo: NOAA library

12.1. Coastal and Marine Species

The shores of Cape Cod and the islands provide important migratory, resting, breeding and nesting areas for a large number of migratory coastal and marine birds. In particular, pelagic birds and waterbirds have formed colonies in various coastal areas (Figure 29 and Table 6, Veit and Petersen, 1993). Several of the largest tern colonies in New England are located within 20 miles of Horseshoe Shoals. Approximately 50 percent of the North American population of federally endangered Roseate Terns breeds in Buzzards Bay (U.S. Fish and Wildlife Service, 1998) and in 2003, approximately 10,000 pairs of Common Terns nested at Monomoy (Carolyn Mostello, personal communication to Perkins et al., 2003). In late summer during the fall migration, the Roseate Terns that stage in Chatham may represent nearly the entire North American population of Roseate Terns (Trull et al., 1999).

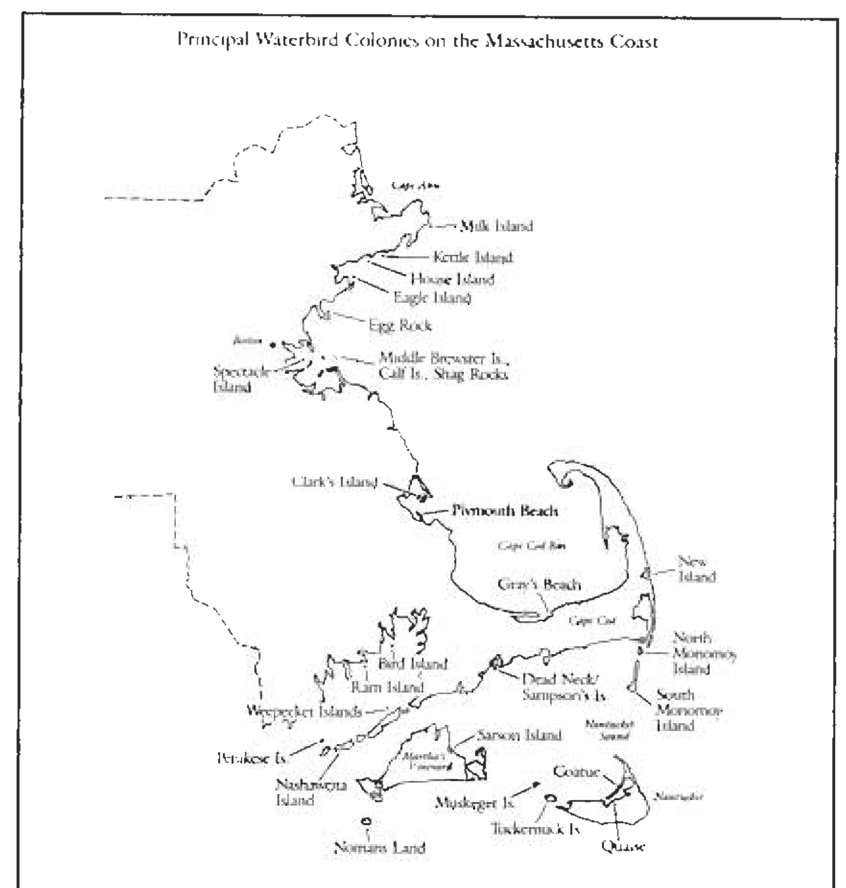


Figure 29. Principal Waterbird Colonies on the Massachusetts Coast. From Veit and Petersen (1993).

Table 6. Principal areas in Massachusetts where waterbirds form colonies (Veit and Petersen, 1993).

Colony Name	Double-crested Cormorant	Great Egret	Snowy Egret	Little Blue Heron	Cattle Egret	Black-crowned Night-Heron	Glossy Ibis	Laughing Gull	Herring Gull	Great Black-backed Gull	Roseate Tern	Common Tern	Arctic Tern	Least Tern
Milk Island	717								1330	700				
Kettle Island			33	4		18	11		437	46				
House Island									280	75				
Eagle Island			2		2	42			375	50				
Egg Rock	304								135	62				
Spectacle Island		1	40			60	10		920	36				
Middle Brewster Island	92		124			270			1400	110				
Calf Island			25			50	1		810	149				
Shag Rocks	886								17	3				
Clark's Island		2	127	1		235			1813	156				
Plymouth Beach											6	1114	6	17
Gray's Beach											64	856		
Dead Neck/ Sampson's Island			1			20			300	90	53	168		15
New Island								254			40	1540	6	
North Monomoy Island								800	570	63	2	1200	3	2
South Monomoy Island			85			82			13,951	4933				35
Bird Island											1650	810		
Ram Island									500	90				
Weepecket Islands	1135								658	130				
Nashawena Island			30			20			930	200	2	145		68
Penikese Island									383	8				
Sarson Island			2						175	5		250		

(**Table 6.** continued)

Colony Name	Double-crested Comorant	Great Egret	Snowy Egret	Little Blue Heron	Cattle Egret	Black-crowned Night-Heron	Glossy Ibis	Laughing Gull	Herring Gull	Great Black-backed Gull	Roseate Tern	Common Tern	Arctic Tern	Least Tern
Nomans Island			13			60			1200	200	3	150		1
Muskeget Island									250	750				
Tuckermuck Island									800	400				200
Coatue		1	11			42			970	679				
Quaise		1	45			9								

Shaded rows represent areas bordering Nantucket and Vineyard Sounds.

Although land observations and banding studies of birds are abundant due to public interest in birdwatching, these types of studies provide data only at points where humans catch or observe the birds, which are generally on land or occasionally at sea. The detailed migration paths and patterns of birds <u>through</u> the Nantucket Shelf area has generally not been studied, with one exception: a study by the Massachusetts Audubon Society, conducted in 2003, to study tern activity within Nantucket Sound during the 2003 breeding season, and in particular activity of the endangered Roseate Tern (Perkins et al., 2004). This study is important because it used rigorous methods for observing and documenting avian use of airspace over the water.

Perkins' team used aerial flights and boat surveys across a portion of Nantucket Sound (Horseshoe Shoals) and collected data on abundance, distribution, behavior, flight heights, and temporal changes in behavior of Common Terns and the federally endangered Roseate Tern (Figures 30 and 31, Perkins et al., 2004). Their results showed that:

1) The greatest numbers of birds of both species were documented early in the survey period (May through the first half of June); numbers decreased thereafter, with one peak in late July.
2) Most of the birds observed on Horseshoe Shoals were traveling rather than fishing or sitting on the water ("rafting").
3) Slightly greater numbers of birds were recorded on the southern part of Horseshoe Shoals, possibly in response to stronger currents that create stronger upwelling, bringing plankton and baitfish near the surface for terns to feed upon;
4) The Monomoy colony contained about 63 percent of all the breeding Common Terns in Massachusetts (approximately 10,000 pairs).
5) The altitude range of all traveling terns was between 5 and 250 feet, with an average height of 29 feet (median height of 25 feet).
6) Horseshoe Shoals may be more important as a migratory stopover point or "refueling" area than as a feeding area for locally nesting resident terns.

Other state-listed endangered or threatened birds that utilize the shores of the Cape and islands include the Piping Plover (*Charadrius melodus*) and potentially the Bald Eagle (*Haliaeetus leucocephalus*) (Massachusetts Natural Heritage and Endangered Species Program).

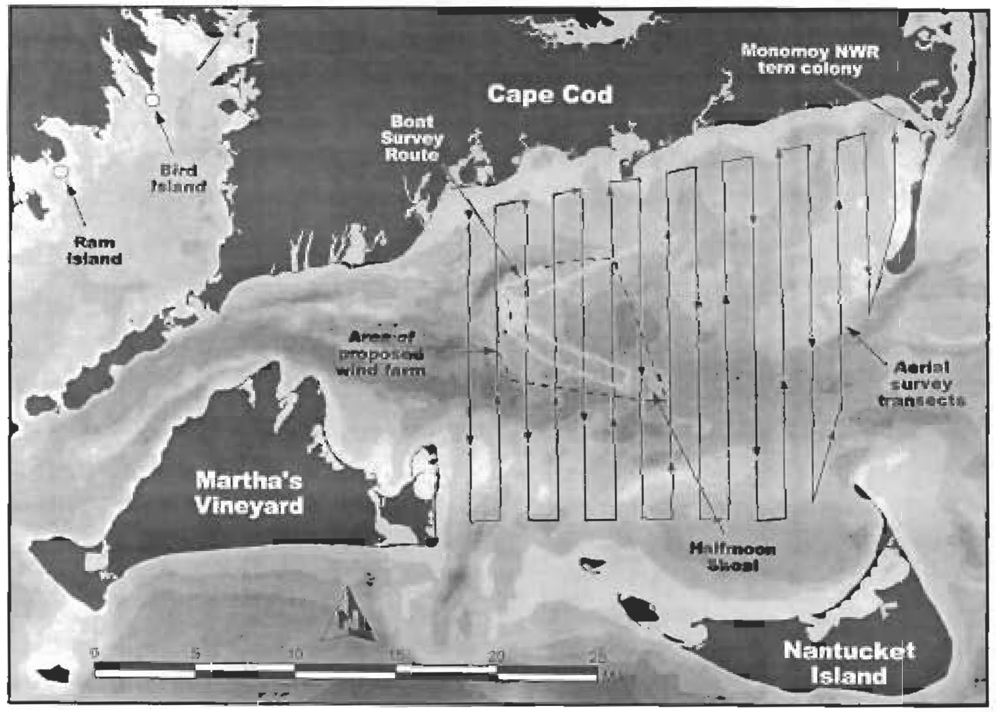


Figure 30. Nantucket Sound study area and associated features, including aerial and boat transect routes, and the area of proposed wind farm, major tern colonies. Figure 1 from Perkins et al. (2004).

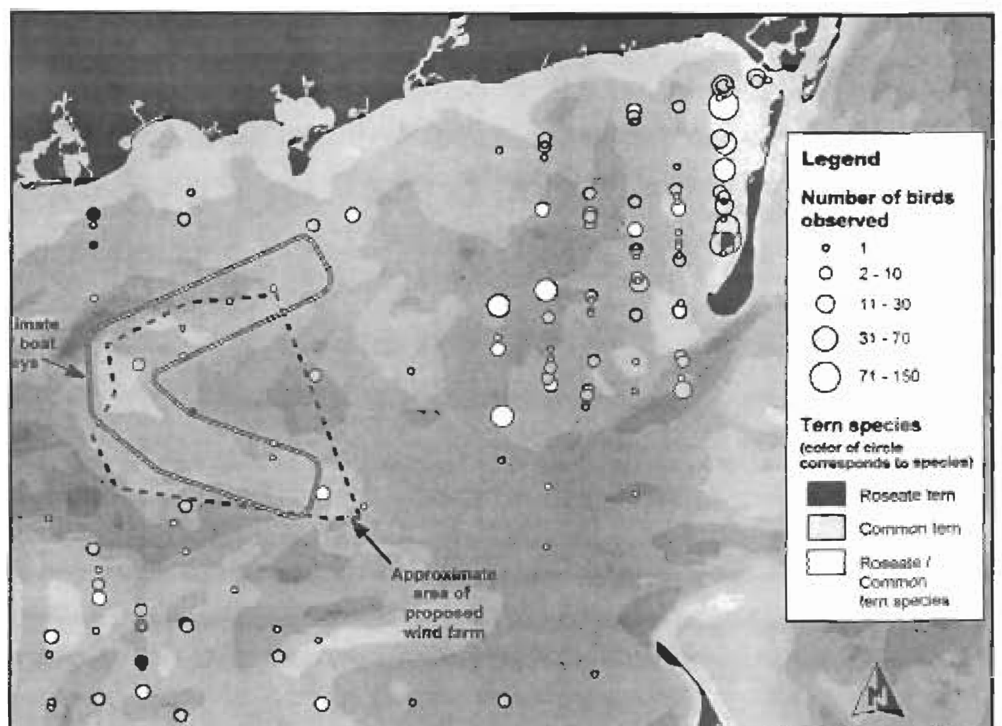


Figure 31. Summary distribution map of terns by species observed during 2003 breeding season aerial surveys of Nantucket Sound. Number of terns seen at any one location represents the combined total of three aerial surveys and the magnitude indicated by the diameter of the circle. Perkins et al. (2004).

In all, a total of 190 species of marine and coastal birds have been observed along the entire Atlantic coast from Florida to Maine (Table 7). Of these, which approximately 131 species have been observed along the Massachusetts coast along the Atlantic Flyway, in the nearshore area or far offshore (Hoopes et al., 1994, 4 volumes). These species are listed below (note that many of these sightings would be rare, occasional, observed only far offshore, or accidental):

Table 7. Marine and Coastal Birds observed along the Atlantic Coast. From Hoopes et al. 1994.

Red-Necked Grebe	Black Tern	Harlequin Duck	Sanderling
Horned Grebe	Black Skimmer	Common Eider	Bar-Tailed Godwit
Pied-Billed Grebe	Black-Browed Albatross	King Eider	Willet
Common Loon	Northern Fulmar	Black Scoter	Ruff
Arctic Loon	Cory's Shearwater	White-Winged Scoter	Buff-Breasted Sandpiper
Red-Throated Loon	Greater Shearwater	Surf Scoter	Eurasian Curlew
Atlantic Puffin	Manx Shearwater	Ruddy Duck	Whimbrel
Black Guillemot	Audubon's Shearwater	Canada Goose	Black-bellied Plover
Common Murre	Black-Capped Petrel	Brant	Killdeer
Thick-Billed Murre	Leach's Storm-Petrel	Barnacle Goose	Piping Plover
Razorbill	Wilson's Storm-Petrel	Mute Swan	Ruddy turnstone
Dovekie	White-Faced Storm-Petrel	Wood Stork	American Oystercatcher
Great Skua	White-Tailed Tropicbird	American Bittern	Northern Harrier
South Polar Skua	Brown Booby	Least Bittern	Bald Eagle
Pomarine Jaeger	Northern Gannet	Great Blue Heron	Peregrine Falcon
Parasitic Jaeger	Great Cormorant	Great Egret	Osprey
Long-Tailed Jaeger	Double-Crested Cormorant	Snowy Egret	Belted Kingfisher
Ivory Gull	Common Merganser	Tricolored Heron	
Black-Legged Kittiwake	Red-Breasted Merganser	Little Blue Heron	
Glaucous Gull	Hooded Merganser	Cattle Egret	
Iceland Gull	Mallard	Green-Backed Heron	
Great Black-Backed Gull	American Black Duck	Black-Crowned Night Heron	
Lesser Black-Backed Gull	Gadwall	Yellow-Crowned Night Heron	
Herring Gull	Eurasian Wigeon	King Rail	
Ring-Billed Gull	American Wigeon	Virginia Rail	
Common Black-Headed Gull	Green-Winged Teal	Sora	
Laughing Gull	Blue-Winged Teal	Yellow Rail	
Franklin's Gull	Northern Pintail	Red Phalarope (oceanic)	
Bonaparte's Gull	Wood Duck	Black-Necked Stilt	
Little Gull	Redhead	Long-Billed Dowitcher	
Ross's Gull	Canvasback	Stilt Sandpiper	
Sabine's Gull	Greater Scaup	Red Knot	
Forster's Tern	Lesser Scaup	Purple Sandpiper	
Common Tern	Ring-Necked Duck	Pectoral Sandpiper	
Arctic Tern	Common Goldeneye	White-Rumped Sandpiper	
Roseate Tern	Barrow's Goldeneye	Dunlin	
Least Tern	Bufflehead	Semipalmated Sandpiper	
Bridled Tern	Oldsquaw	Western Sandpiper	

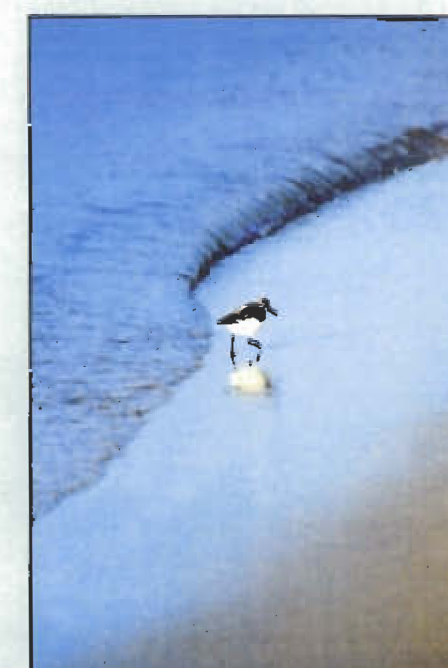


photo: NOAA library

12.2. Issues and Data Gaps

It would be useful to develop a three-dimensional map of the airspace above the Massachusetts coastline and the Nantucket Shelf Region, showing observations of marine and coastal birds, migration routes and activities. Using modern computerized methods and Geographic Information System (GIS) mapping, this could eventually be done. The resulting database and map would be useful for resource managers looking for comprehensive information in order to manage many species, rather than managing for one or two species.

The role of healthy fisheries and benthic habitats in sustaining many coastal and marine birds should be quantified. The relationship between oceanic productivity and coastal and marine bird activity should also be quantified, as many of these species are endangered or threatened or otherwise rare.

photo: NOAA library

13. SEA TURTLES

13.1. Sea Turtles In Massachusetts

Sea turtles are turtles which live their entire lives at sea, with the exception of coming ashore to lay their eggs on tropical beaches. Five species of sea turtles can occur in Massachusetts offshore waters, and all four are state-listed and/or federally listed as endangered or threatened. They include:

- Hawksbill sea turtle (*Eretmochelys imbricata*) – Endangered
- Kemp's Ridley sea turtle (*Lepidochelys kempii*) – Endangered
- Leatherback sea turtle (*Dermochelys coriacea*) – Endangered
- Loggerhead sea turtle (*Caretta caretta*) – Threatened
- Green turtles (*Chelonia mydas*) - Endangered

Sea turtles generally spend more time in the warm waters of the Caribbean, mid-Atlantic or Gulf of Mexico, but some travel to cooler temperate waters. Three species commonly use Stellwagen Bank for foraging: the leatherback, the loggerhead, and Kemp's Ridley.

The Leatherback has been known to travel as far north as Labrador. Loggerheads are the most numerous of the sea turtles found along the New England coast, but they cannot tolerate cold water and are not found north of Stellwagen Bank. Kemp's Ridley is particularly susceptible to cold and they frequently die of exposure; studies indicate that the waters south of Cape Cod may be the northern limit of their range (reviewed in Ward, 1995).

Threats to sea turtles in the marine environment include:

- Entanglement at sea in longlines, fish trap warps, buoy anchor lines, and other ropes and cables
- Ingestion of marine debris
- Commercial fisheries
- Boat collisions
- Oil and gas exploration, development transportation and storage
- Pollution

Sea turtles are in extreme jeopardy worldwide. Because they nest on tropical or subtropical beaches, many of which are outside the U.S., impacts include destruction of their nesting habitat by coastal development, beach nourishment, dredging, and other nearshore or onshore activities (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991; 1992; 1993).

13.2. Issues and Data Gaps

The effect of commercial fisheries on sea turtle populations in the Nantucket Shelf area, both through direct impacts (entanglement) or indirect effects (damaging benthic habitat and causing prey food, such as invertebrates and shellfish, to become scarce), needs to be better understood. A comprehensive benthic habitat monitoring program using multisensor methods, like those conducted by the USGS and NMFS, should be conducted to evaluate habitat impacts.

Similarly, the effects of coastal pollution on sea turtles needs to be evaluated, particularly as coastal development increases along the southeastern Massachusetts coast.

Methods to help stranded or cold-stunned sea turtles need to be improved. A National Marine Life Center has been built in Buzzards Bay to provide such care for stranded or cold-stunned or injured sea turtles and smaller marine mammals.

Global climate change may result in changing largescale ocean circulation. Sea turtles prefer warm water, so if ocean circulation off the mid-Atlantic and New England coast changes, it may affect the routes and distribution of sea turtles.

14. DISCUSSION

Vineyard Sound, Nantucket Sound, Nantucket Shoals, the shelf south of Martha's Vineyard, and the Great South Channel all form part of a large shallow coastal shelf ecosystem that is characterized by a common geological origin, highly dynamic sedimentary environment, shallow clear water that is vigorously mixed and well-aerated by fast tidal currents, and high phytoplankton productivity. Because of these shared features, this area should be treated as one marine ecological unit, the Nantucket Shelf region. Other nearby areas which share a similar geological origin and physical characteristics include Georges Bank and Stellwagen Bank.

The Nantucket Shelf ecosystem can be summed up in the following ways:

- Highly dynamic water flow and circulation, creating well-oxygenated and well-flushed system;
- Highly dynamic sediment system is probable, based on current speeds and sediment grain size, but more information is needed to map benthic habitats. It is probable that sedimentary bedforms (e.g., sand waves, sand ripples, other features) exist that would provide essential fish habitat;
- High primary productivity year-round, and may serve as a source of nutrients and plankton for adjacent offshore areas through advection and transport by rapid tidal currents out of Nantucket and Vineyard Sounds, but this should be confirmed through scientific studies;
- Transition zone between southern and northern biogeographic provinces;
- Located in an important bird migration corridor, the Atlantic Flyway (birds, sea turtles, fish, whales);
- Islands and shorelines provide important nesting, breeding, and feeding habitat for coastal birds and seals, including some state-listed and federally-listed endangered species;

- Coastal areas contain suitable shellfish habitat, which could be improved by improving water quality;
- Nantucket Shelf region and its estuaries are rich in fish, although the fishery was probably more extensive in the past, and the area doubtless serves as a nursery habitat for Anadromous and Catadromous fish. Nursery habitat ecology deserves more scientific study.
- Contains rich whale feeding grounds in the Great South Channel, fed by blooms of copepods that may be advected from elsewhere. This area should be protected due to the importance of the area for the endangered right whale;
- Extensive area of shallow shelf sands may absorb storm wave energy and lessen coastal erosion; and
- Data gaps are significant and include: lack of information on sedimentary environments and benthic habitats, impacts on benthic habitats, benthic ecology and taxonomy, physical oceanography, residence times, water quality, water and nutrient advection into and out of the area and implications for the area serving as a "feeder" zone to nearby marine waters, longterm effects of coastal water quality on nearby coastal areas, nursery areas for fish and other species based on tagging studies, effects of declining fisheries and other living resources on predators (birds, marine mammals) and marine ecology in general.

Remote-sensing of ocean color for chlorophyll mapping indicates that the Nantucket Shelf Region, like Georges Bank, Stellwagen Bank and other shallow shelf areas, has high primary productivity year-round. This remarkable fact suggests that the Nantucket Shelf Region should be as productive a fishery as Georges Bank once was.

The year-round primary productivity, combined with the tidal currents that race across Vineyard and Nantucket Sounds and Nantucket Shoals, also suggest that nutrients and plankton may be carried into adjacent areas, such as the Great South Channel. The Great South Channel is remarkable for its copepod blooms which attract the endangered right whale and other marine mammals and fish. Although our hypothesis that the Nantucket Shelf Region acts as a source of nutrients to adjacent areas is only conjecture, the one single lesson of ecology is that all ecosystems are ultimately connected through physical, chemical and biological processes. This is especially true for ecosystems located next to each other.


photo: k.king

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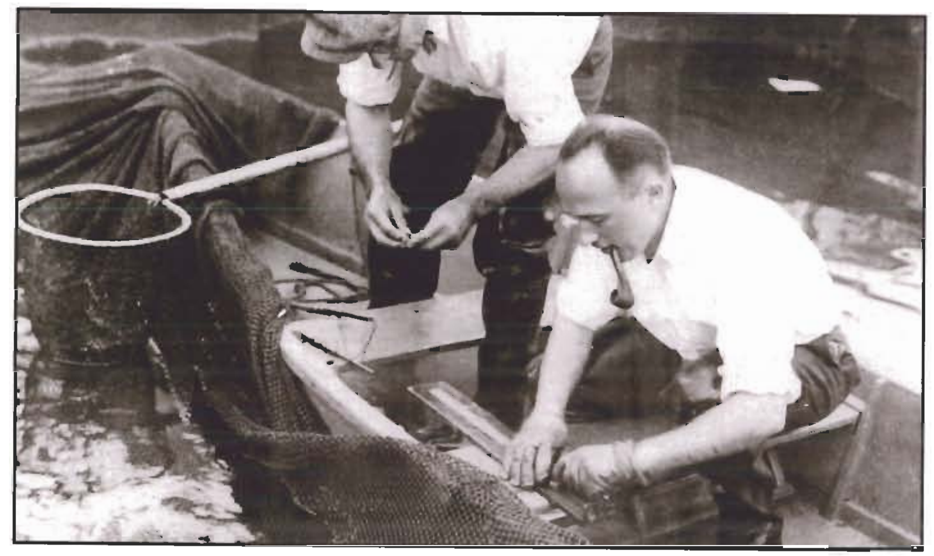

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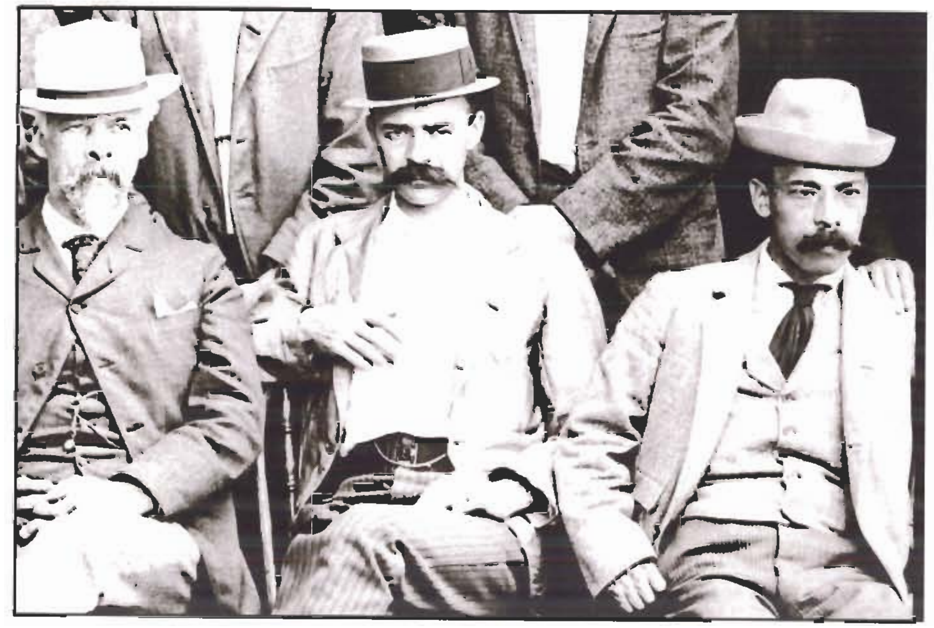

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right to left: Chilchester, Galtsoff, Smith, unknown, Bigalow.
Photographer: Galtsoff, Paul - historic collection - NOAA Photo Libary

Part II.
Management Options For Resource Protection and Sustainable Uses

1. INTRODUCTION

The Nantucket Shelf Region is one of the most heavily used ocean areas in the Northeast, due to its bountiful natural resources, proximity to major population centers, and rich fishing grounds. A wide range of coastal management issues, human activities and cultural values characterize this area. The region's natural resources and beauty are threatened by increasing coastal development, associated water quality problems, conflicting uses, and increasing intensity of use. There is no comprehensive regional coastal and ocean management plan for this important ocean sector.

Part II of this report explores possible options for comprehensive protection and management of the Nantucket Shelf Region. The goal of this analysis is to identify and recommend measures that will protect the key environmental, ecological, and human values of this region while allowing and promoting sustainable human activities.

Part II begins with a discussion of recent calls for ocean protection and the timeliness of ocean protection. Section 2 describes the ocean-based human uses and socioeconomic values of the Nantucket Shelf Region. Existing coastal management issues facing the region are described in Section 3. Section 4 describes existing ocean management approaches that have been used in the region or considered for other ocean areas. Key principles for sound ocean management are described in Section 5. Section 6 discusses ecological and socioeconomic criteria for siting Marine Protected Areas. Section 7 evaluates possible ocean management approaches that could be applied to the Nantucket Shelf Region.

The management and protection of the Nantucket Shelf Region is currently provided through a myriad of local, state, regional and federal laws and agencies that are disjointed, sometimes conflicting, and occasionally lacking the appropriate authority to manage. Regional ecosystem-based management may be the solution to disjoint and incomplete ocean management. This is a conclusion reached by a number of state and federal commissions and agencies which have recommended that the U.S. should provide better protection of its coastal and ocean waters. These include the following:

- The U.S. Commission on Ocean Policy has recommended increasing protection of our oceans, applying Marine Protected Areas as a protection approach, increasing scientific research on the oceans, using ecosystem-based management, and providing more outreach concerning the importance of the oceans (U.S. Commission on Ocean Policy, 2004).
- The Pew Ocean Commissions Report (2003) identified 9 major challenges for America's oceans, including nonpoint and point source pollution, invasive species, aquaculture wastes, climate change, bycatch, habitat alteration, overfishing, and coastal development.
- Executive Order 13158, May 26, 2000, calls for the establishment of Marine Protected Areas to "help protect significant natural and cultural resources within the marine environment for the benefit of present and future generations." (Federal Register, Volume 65, No. 105, May 31, 2000, Presidential Documents).

Whale Watch out of Hyannis Photo: IFAW

- In 2003, the Governor established the Massachusetts Ocean Management Initiative, whose goals are to proactively manage ocean resources within the 3-mile state jurisdictional limit, work with federal agencies to improve ecosystem-based management of ocean resources in federal waters, and improve management and protection of environmental, planning and public trust issues in both state and federal waters (see http://www.mass.gov/czm/oceanmgtinitiative.htm).
- The science of managing ocean reserves is at the leading edge of natural resource management policy because of rapid and radical degradation of the world's oceans (U.S. Commission on Ocean Policy, 2004; Lubchenco et al., 2003; Cicin-Sain and Knecht, 1998).
- At the international level, the use of Marine Protected Area (MPA) designation is being utilized in many countries and is strongly supported by many international ocean programs. International agencies like USAID and the World Bank are funding MPAs and regional ocean protection initiatives (NOAA Coastal Services Center, March 2002; U.S. Commission on Ocean Policy, 2004).

The need for regional ocean protection is a worldwide need, because the oceans represent a common heritage for all of mankind.

2. HUMAN USES AND SOCIOECONOMIC VALUES

The Cape and Islands have a long tradition of maritime activities and environmental protection. These human uses and cultural values were described in the 1980 Nomination Letter for a National Marine Sanctuary in Nantucket Sound, but they also apply to the larger Nantucket Shelf Region discussed here (Massachusetts Coastal Zone Management, Department of Environmental Management, Division of Marine Fisheries, 1980). The region contains regionally and nationally significant historic, recreational, scientific, socioeconomic and aesthetic resources that are ocean-based. These are described in more detail below.

Maritime Tradition

The sea has shaped the history, life and culture of the Nantucket Shelf Region. In the 16th century, fishermen from Portugal and other European countries discovered the rich fishing grounds of Georges Bank and Cape Cod. The Pilgrims and other English colonists arrived and began settling Cape Cod, Martha's Vineyard and Nantucket in the early 17th century. During the 18th and 19th centuries, colonists and settlers cleared and sold timber to shipyards, set up a salt industry to evaporate seawater to obtain the salt, and provided ship-building and maintenance services. Tourism became important in the second half of the 19th century and has continued to be an important industry ever since.

The New England fishing and whaling trade reached its peak during the early 19th century. At its peak, the Nantucket whaling fleet of 88 vessels sailed far afield in search of whales, even into the remote South Pacific, returning to Nantucket to offload their precious cargo. Nantucket was the leading whaling port in the world then, and was also the third largest city in Massachusetts, after Boston and Salem (Nantucket Chamber of Commerce website at http://www.nantucketchamber.org/visitor/trivia.html). In recognition of its important role in national and international maritime history, the entire island of Nantucket was included in the U.S. National Register of Historic Landmarks in 1975 (Massachusetts Coastal Zone Management, Department of Environmental Management, Division of Marine Fisheries, 1980).

Today, the Cape and Islands continue to provide a variety of maritime uses and maritime industries. These include commercial and recreational boating, fishing and shellfishing; shellfish aquaculture; working boatyards and marinas; oceanographic and coastal research and education; and coastal tourism. A number of military facilities exist in the area, including a Coast Guard facility in Woods Hole, Pave Paws radar facility in Bourne, the Massachusetts Military Reservation, and an facility at the Cape Cod National Seashore. Commercial and private aviation facilities are busy, due to the popularity of the Cape and Islands as a tourist destination and the need for regular commuting services, and the Barnstable Municipal Airport is the third busiest airport in the Commonwealth of Massachusetts.

Human Uses and Activities

Cape Cod, Martha's Vineyard and Nantucket and its surrounding waters have long been one of the most popular tourist destinations along the East Coast. The popularity of this region is due to its natural scenery, proximity to major urban centers, agreeable summer climate, and easy access. Each year, hundreds of thousands of people visit the beaches, while others participate in recreational boating and fishing, swimming, and other water sports. The low topographic relief encourages bicycling, walking and family activities. In the well-mixed, productive waters of Nantucket and Vineyard Sounds and beyond, water quality is good and promotes recreational shellfishing, fishing and boating.

photo: NOAA photo library

Boating is an important recreational activity in the Nantucket Shelf Region. The proximity of the islands to the mainland of Massachusetts promotes traffic to and from the islands and Cape Cod and the mainland. The narrow channels and fast currents of Vineyard Sound and Nantucket Sound provide challenging sailing within close proximity to Boston, Providence, and other growing communities in Southeastern Massachusetts. Ferry service exists between Provincetown and Boston, Cape Cod and the Islands, and New Bedford and the islands. The shallow shoals surrounding Nantucket and Vineyard Sounds excludes large commercial vessels, thus making the region attractive for recreational boaters.

Coastal tourism is a vital part of the year-round economy of the Cape and Islands. For year-round residents who work in service industries (restaurants, rental accommodations, transportation, retail shops and markets, etc.), tourism is essential for maintaining adequate annual incomes. Economic data collected by the Cape Cod Commission indicates that in 2003, nearly one-third of all Cape Cod jobs were related to travel (travel is defined by the Massachusetts Office of Travel and Tourism as including 16 categories of public and auto transportation, travel arrangement, retail, food, accommodations, entertainment and recreation industries). In 2001, annual travel-related jobs on Cape Cod alone averaged 29,506, or 32.9% of the 89,761 public and private-sector jobs in Barnstable County. At their peak in July, travel-related jobs accounted for 39.3% of all 102,131 Cape jobs. Jobs in eating and drinking establishments led all industries, averaging 12.1% of all Cape jobs (10,845 jobs). At their peak in July of 2001, jobs in this sector were 15.7% (16,072 jobs) of the total number of jobs (Cape Cod Commission, August 14, 2003).

Martha's Vineyard businesses are even more dependent on seasonal tourism. The Martha's Vineyard Commission reports that in a recent survey of business owners, 77.8% of businesses relied upon seasonal tourism, and at least one-third of all businesses said that more than 75% of their businesses were dependent on tourism (http://almanac.vineyardconservationsociety.org/mvc/mvc-mainpage.shtml).

As another indicator of the importance of coastal tourism, Cape Cod's state room tax revenues (state 5.7% room occupancy tax) reached $12.5 million in 2003. This figure represents 15% of the total statewide ($83.1 million) collection of room tax revenues (Cape Cod Commission, August 14, 2003). In economic terms, therefore, the tourism industry is important for Cape Cod and the Islands and provides a significant portion of the state's economy.

Coastal and Marine Science, Technology and Education

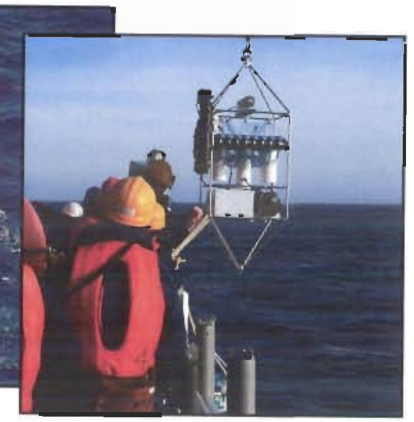
Coastal and marine science, technology and education figure prominently in the history, culture and economics of the Nantucket Shelf Region. The unusual concentration of educational and scientific institutions, museums, reserves, and parks devoted to marine science, technology and education is unique in the Northeast. High-tech small businesses and industries based upon oceanographic instrumentation and marine products and technology have sprung up as an outgrowth of science and technology institutions in the area.

Marine Biological Laboratory scientists. photo: NOAA Archive

Scientific research in marine biology and oceanography became established in the late 19th century, beginning with the Marine Biological Laboratory, followed by the Woods Hole Oceanographic Institution in the early 20th century. There are research facilities for the NOAA National Marine Fisheries Service and U.S. Geological Survey in Woods Hole, while a number of non-profit scientific research organizations are also located in the region (e.g., Woods Hole Research Center, Nantucket Field Station, Center for Coastal Studies).

Researchers investigating an oil spill. photo: WHOI

Rescuers attempt to free an entangled whale. photo: WHOI



Oceanographers deploy a sensing instrument. photo: WHOI

Marine educational institutions include SEA (Sea Education Association), the Waquoit Bay National Estuarine Research Reserve (WBNERR), and a network of marine educators coordinated through the Woods Hole Science and Technology Education Partnership (WHSTEP).

WBNERR also serves as a hub of coastal environmental education and management activities that involve the Department of Environmental Management, NOAA, and the Massachusetts Office of Coastal Zone Management. Marine animal research and rescue operations include the National Marine Life Center and the Cape Cod Stranding Network in Bourne, Massachusetts Audubon Sanctuary in Wellfleet, NOAA National Marine Fisheries Service, and the Center for Provincetown Coastal Studies. The Massachusetts Maritime Academy in Bourne provides marine and military training in marine engineering, navigation, coastal issues, and practical seamanship.

A number of non-profit and government agency-operated museums and natural history centers are located in the Nantucket Shelf Region (e.g., Cape Cod Museum of Natural History, Cape Cod National Seashore, respectively). Technical assistance for addressing a variety of coastal and environmental issues is available from a number of agencies, including the Buzzards Bay Project, the Cape Cod Commission, the Martha's Vineyard Commission, Barnstable County Extension, regional Coastal Zone Management for the Cape and Islands, and Wampanoag Tribal natural resource departments.

To recap, the open waters of the Nantucket Shelf Region are the wellspring of the history, economy, culture, science, and natural beauty of the region. Tourism and recreational activities in the Cape and Islands literally depend upon the attractive, open, undeveloped character of the coastal and ocean waters of the region. Coastal and marine science, technology and education are particularly active in the region and are an important economic and cultural force.

photo: NOAA photo library

Aesthetic Value

In the 21st century, although maritime industries such as marinas and fishing continue, the principal outstanding value of the entire region may lie in its natural beauty. The natural beauty of the Nantucket Shelf Region is based upon open, undeveloped coastal and ocean vistas. The coastal scenery of the Cape and Islands encompasses dunes, beaches, low hills, coastal plains, salt marshes, islands and scenic water vistas. The extensive beaches, quiet estuaries, the proximity to important whale feeding grounds off Provincetown, the rich bird life, and other natural features, are highly attractive to those who enjoy nature.

Protecting the natural scenery of the Cape, Martha's Vineyard and Nantucket is a high priority for the residents of the region. Local voters have approved land protection and management measures such as regional development agencies (Cape Cod Commission, Martha's Vineyard Commission, Nantucket Regional Planning Council), regional growth management planning, Cape Cod Land Bank, active volunteerism, and the passage of local ordinances protecting natural resources.

Thus, despite the rapid pace of coastal development, many coastal land areas are protected or managed through local zoning or regional planning, or through designation as a national park, wildlife refuge, National Estuary, or other means of protection. Coastal waters within the 3-mile state jurisdiction are protected from development activities under the Massachusetts Ocean Sanctuaries Act, which designated three state ocean sanctuaries in southeastern Massachusetts: Cape and Islands Ocean Sanctuary, Cape Cod Bay Ocean Sanctuary, and Cape Cod Ocean Sanctuary. However, significant areas of coastal waters outside the 3-mile state limit remain unprotected.

Coastal erosion. photo: WHOI/raubenheimer

3. COASTAL MANAGEMENT ISSUES

There are many coastal management issues in the Nantucket Shelf Region, owing to its popularity as a tourist destination, coastal development, and the many recreational and commercial activities that are ongoing or possible. Some of these activities have already caused environmental impacts. Some of the most significant coastal management issues are listed below:

- Coastal development and population growth;
- Water quality impacts (contaminated groundwater plumes, coastal nutrient loading, nonpoint source pollution, atmospheric deposition of pollutants, floatables, pathogens);
- Fishery activities;
- Boating;
- Offshore mining of sand, gravel, oil and gas;
- Other potential uses requiring infrastructure and/or disturbance of natural resources (e.g., proposed wind farm, potential future desalinization for water supply, outfall pipes, etc.);
- Offshore utilities;
- Poor air quality during the summer;
- Sea level rise and climate change;
- Coastal erosion and flooding;
- Habitat loss resulting from all of the above;
- Significant information gaps concerning offshore resources;
- Environmental contamination and security issues related to the presence of military installations (e.g., Massachusetts Military Reservation, Pave Paws radar installation) and energy facilities (e.g., Canalside power plant, Plymouth nuclear power plant); and
- The incomplete patchwork of different coastal protection and management measures in Southeastern Massachusetts.

Some important ocean management issues are described in more detail below.

Coastal Development

Coastal population growth and development pose some of the biggest environmental challenges for coastal managers (U.S. Commission on Ocean Policy, 2004). Coastal development poses one of the most significant impacts on coastal and marine ecosystems, because it has such wide-ranging effects. Coastal development and increasing human use of the coastal zone generally impacts water quality, decreases habitat, lessens

Cape Cod shoreline photo: MASSGIS

quality of life, increases coastal hazards related to sea level rise, and increases need for energy, water and public infrastructure for the expanding population. Increased nonpoint and point source discharges of nutrients, pathogens, and other contaminants are inevitable. As the population grows, so too will the cumulative impacts on the marine ecosystem increase.

Cape Cod, Nantucket and Martha's Vineyard experienced some of the most rapid population growth in Massachusetts, based on the 2000 U.S. census. While the statewide population growth rate between 1990 and 2000 was 1.3%, Barnstable County, Nantucket County and Duke's County year-round populations increased by 3.3%, 12.6%, and 4.1%, respectively. Cape Cod alone was estimated to rank fifth in the state in terms of overall population growth by July 2003 (Cape Cod Commission, August 5, 2004, http://www.capecodcommission.org). In the 2000 census, Cape Cod's year-round population was 222,220, and the summer population reportedly swells to more than three times this number (http://www.barnstablecounty.org/). The year-round populations of Nantucket County and Duke's County (Martha's Vineyard) in the 2000 U.S. census were 9,520 and 14,987, respectively.

Cape Cod, Martha's Vineyard and Nantucket have regional development commissions which regulate larger development projects and provide guidance for smaller development projects. These are the Cape Cod Commission, the Martha's Vineyard Commission, and the Nantucket Planning and Economic Development Commission, respectively.

The long-term cumulative effects of coastal pollutant loading on the Nantucket Shelf Region have not been studied with the goal of developing a detailed model of how coastal pollutants behave in the Nantucket Shelf region. Studies of coastal pollutant loading typically focus on coastal embayments on Cape Cod and the Islands and assume that once pollutants reach marine waters, they will be flushed away by the rapid currents. But the larger questions of the long-term effect or whether the Nantucket Shelf thereby acts as a source of pollutants to nearby areas of the shelf have not been posed.

Similarly, the long-term cumulative effects of a number of human activities and natural processes on the entire Nantucket Shelf Region have not been studied.

Water and Wastewater


Wastewater treatment plant. photo: AWWA

Water quality and water quantity can both deteriorate as coastal communities expand. Although freshwater rivers and streams on the Cape and Islands are small in terms of flow, they serve as conduits for watershed pollutants to enter the sea. Increased withdrawal of groundwater and surface water for drinking water supplies will tend to deplete the groundwater aquifer and cause streams to become less of a factor in estuarine inputs. Although groundwater recharge could increase as a result of more septic systems that would be needed to handle the wastewater of a growing population, this may occur at slower rates than stream flow rates. One potential consequence is decreased freshwater flow into Vineyard and Nantucket Sounds. If this were to happen, salt water intrusion may also occur.

Salt water intrusion may also occur as a result of sea level rise. The best expert estimate of the rate of sea level rise over the next century is 19 inches (IPCC, 2002). Cape Cod, Nantucket and Martha's Vineyard each have sole-source aquifers that would be subject to saltwater intrusion as sea level rises. Managing water supply at a time when the demand will be growing and the supply will be shrinking will be problematic.

Contamination from wastewater treatment facilities and septic systems already poses significant threats to coastal embayments on Cape Cod and the Islands. The DEP Estuaries Project is focusing on nitrogen loading to coastal embayments on Cape Cod. The potential long-term impact of wastewater on water quality in the Nantucket Shelf Region has not been evaluated, partly because it is always assumed that the vigorous tidal action will disperse and dilute any discharged treated wastewater. However, the efficacy of the reversing tidal currents in dispersing pollutants should be evaluated for the Sounds, as well as the long-term effect of nutrient loading.


photo: NOAA archive

Fisheries Impacts

Although most fishing gear, especially mobile gear, has unintended effects on substrates and benthic communities, damage has been minimized through effective regulation by state, regional and federal agencies. A series of area and seasonal fisheries closures have protected spawning and nursery areas at appropriate times. Similarly, the mesh size of towed nets is regulated to control the bycatch of juvenile and non-target species. Gillnets have been banned in state waters south of Cape Cod to prevent bycatch of non-target species and in the Great South Channel Critical Habitat to protect right whales. Other sectors have increased, including hook and fishpot fisheries. These gears produce less bycatch of juvenile and non-target species, but must be limited in scope to prevent overfishing, and regulated to prevent or minimize entanglements of mammals, birds and turtles.

Since many of the species that spawn and feed seasonally in Nantucket Sound are migratory species, subject to fisheries in other states and the EEZ, they have presented a challenge to regulators, since conservation efforts in one jurisdiction may not be supported in others. Regional fishery management plans, backed by state regulations to control effort in these fisheries, are necessary to achieve coordinated management. The Mid-Atlantic Fisheries Management Council and the Atlantic States Marine Fisheries Commission have instituted hard quotas on migratory species such as squid, scup, summer flounder, black sea bass, and striped bass. In addition to management by gear restrictions and size limits, quotas are an efficient way to control harvest and allocate fishing effort among the states. Modern management plans are designed to allow recovery of depleted species by preventing overfishing throughout the range of each species, at all life stages.

The importance of the Nantucket Shelf Region as a spawning / nursery area for many species, providing important recruitment to populations outside the area, is well - recognized. Similarly, juvenile protection in this area would not be effective unless complemented by protection from small mesh fisheries in the wintering areas to the south and east, and allocated effort on migrating adults.

Boating and Navigation Impacts

Recreational boating activities are popular in Vineyard and Nantucket Sounds. Yet the environmental impacts of such activities are seldom considered. Impacts of boating include proliferation of docks, sediment resuspension due to water turbulence, noise, marine animal strikes, and water quality impacts.

Although scientific research is limited, available studies indicate that small-boat navigation can cause resuspension of sediments in the water column through propeller-driven turbulence (reviewed in Barr, 1993; Crawford et al. (Eds.) and various articles, 1998). In a number of studies, Yousef (1974) and Youset et al. (1978, 1980) found that a 50 horsepower outboard motor had an effective mixing depth of 4.6 meters and bottom sediments were readily resuspended by the same outboard motor in water depths of 1.5 meters or less in a period of 5 minutes of boating activity. The resulting decrease in water clarity and increase in turbidity can cause decreases in seagrass productivity, affect fish, increase concentration of nutrients in the water column, and generally impact water quality (Short et al., 1991; Sherk et al., 1975; Servizi and Martin, 1992; Rhoads et al., 1975; Orth and Moore, 1983; Short et al., 1989).

Boating activity also generates wakes, which can increase bank erosion (Mason and Bryant, 1975; Moss, 1977; Liddle and Scorgie, 1980; Hilton and Phillips, 1982; Garrad and Hey,1988a, 1988b, 1989)

Navigational channels in coastal areas generally require maintenance dredging in order to keep them open. Dredging is often done to help improve water quality in coastal ponds. There can be temporary adverse effects on water quality due to sediment and nutrient resuspension during dredging. Shoreline alteration and habitat alteration can also occur as a result of dredging.

Sea-Level Rise and Climate Change

As a result of global warming due to both natural and manmade causes, sea level has been rising quickly and is expected to continue to rise (IPCC, 2002). Best scientific estimates of the rate of sea level rise over the next century is that sea level will rise on average by 19 inches (IPCC, 2002). The U.S. Geological Survey has been evaluating coastal vulnerability to sea level rise along the nation's coasts, including the Atlantic Coast and the Cape Cod National Seashore, through the National Coastal Vulnerability Study (Thieler et al., 2002; Thieler et al., 2001; Thieler and Hammar-Klose, 1999). Based on such studies, much of the shoreline along the Outer Cape, from Monomoy Island to Provincetown, already lies within a high-hazard area due to the probability of increased flooding and storm wave damage as sea level continues to rise. These studies highlight the seriousness of global warming and sea-level rise on these coastal areas.

Global warming also may result in changes in currents and storm frequency and intensity. As the atmosphere warms, hurricanes and storms may become more intense and coastal erosion would increase as a result. The patterns of ocean circulation may change. Southern species will move north. Such largescale changes in the environment need to be taken into account when planning for protection and management of a region.

The sandy shoals of the Nantucket Shelf Region may potentially play a role in absorbing storm wave energy and lessening storm damage due to waves and currents. The potential role of offshore shoals in lessening storm damage in the Nantucket Shelf Region needs to be better understood. The Nantucket Shelf Region is one of the few areas along the Massachusetts coast where significant sand deposits lie offshore. Paradoxically, the Massachusetts coastline is experiencing net erosion due to sand loss from coastal sand systems, partly due to rising sea level and partly due to coastal armoring which has blocked sand transport and sand sources (Thieler et al., 2001).

Oil and Gas Exploration, Mining and Development


Oil rig. photo: NOAA archive

In 1980, the Massachusetts Coastal Zone Management identified oil and gas exploration and development on Georges Bank as a potential concern for Nantucket Sound, due to the potential for environmental, ecological and aesthetic impacts from oil transportation, oil spills, pipelines, and associated infrastructure and maintenance activities. Nantucket Sound itself was not identified as a potential oil and gas field. Shifting sediment bedforms leading to instability of oil mining platforms, leading to oil spills and impacts on water quality, fish habitat, waterfowl, marine mammals, and sea turtles were also cited as concerns. Navigation was cited as a concern. An oil spill occurring during the nesting season for endangered bird species (Roseate tern) would endanger a major portion of the entire North American population of this species and could impact many other species. An oil spill could have disastrous consequences on the tourist-driven economy if it occurred during the warmer months. The 2003 Bouchard oil spill in Buzzards Bay, involving approximately 98,000 gallons of thick No. 6 oil, resulted in the oiling of approximately 93 miles of coastline, hundreds of birds killed, and long-term impacts on coastal habitat and aesthetic values that are still being evaluated.

Other Proposed Uses

A proposed wind farm involving the placement of 130 wind turbines on the sea floor of Nantucket Sound has generated much concern due to potential impacts on environmental and human values. Concerns range from impacts on recreational boating, bird strikes by the turbine blades, impacts on aesthetic and visual values, and use of a public resource for profit.


Wind farm. photo: WHOI

Another example of potential use of the outer continental shelf is mining of sand and gravel for shoreline beach nourishment. This concept was being discussed in the late 1990's by a number of state and federal agencies and coastal stakeholders. Due to concerns regarding impacts on essential benthic fish habitat, however, the concept has been abandoned for now (R. Haney, Coastal Zone Management, personal communication). Yet the demand for beach nourishment will grow as sea level rises, and offshore sources may provide an economical solution when the cost is compared with buying sand from upland sources (which involves environmental alteration).

Habitat Loss

Habitat loss can occur in airspace, in the water, on the ground and in submerged sediments through a variety of human activities. Habitat loss in coastal areas can occur through coastal development, shoreline alteration, human activities and presence, and habitat degradation. Impacts on benthic habitat can occur through the use of mobile fishing gear and through boating activities that cause sediment resuspension and turbulence. Habitat loss in the water column generally occurs through degraded water quality as a result of pollutants and resuspended sediments, which in turn can cause nuisance or harmful algal blooms. Loss of avian habitat in airspace is probably one of the least well-studied aspects of ecology. Structures that intrude into airspace, such as tall buildings, microwave towers, cellphone towers, utility lines and poles, etc., can pose considerable hazards and cause significant mortalities among birds. In general, avian habitat loss in the Nantucket Shelf Region will be greatest in coastal and nearshore areas, and least in the areas which are less accessible to humans or their activities.

Information Gaps

Despite the region's significant resources, heavy recreational and commercial uses, significant environmental issues, and its strategic position in terms of economy, coastal population and national security, there are some surprising and significant data gaps concerning important natural resources. These data gaps are surprising because they occur in areas that are close to major population centers and in areas where coastal environmental issues have received much attention. Aside from coastal studies along the shore and in coastal embayments, the detailed ecology, physical oceanography, benthic habitat, sedimentology, marine biology, and water quality of the offshore areas in Nantucket Sound and Vineyard Sound are not well-studied. Georges Bank and the Gulf of Maine are better studied, scientifically speaking, than Nantucket Sound, Vineyard Sound, Nantucket Shoals, or the large area of continental shelf south of Martha's Vineyard (Wallace and Braasch, 1996; Wiggin and Mooers, 1992; Backus, 1987).

Incomplete Patchwork of Ocean Protection

Massachusetts coastal waters are protected by a patchwork of different federal and state ocean management jurisdictions. These jurisdictions do not necessarily overlap, nor are they necessarily contiguous. The resulting patchwork has a number of holes in it, in areas where preliminary (and sometimes old) scientific information suggests that the natural resources must be the same as in nearby protected areas. The absence of a single coordinating framework for ocean protection in the Nantucket Shelf Region results in coastal and ocean protection which is patchy and inconsistent.

4. EXISTING OCEAN MANAGEMENT AND PROTECTION

Existing ocean and coastal protection measures include designation of Massachusetts Ocean Sanctuaries for ocean areas within the 3-mile state jurisdictional limit, designation of Buzzards Bay as a National Estuary, designation of the Gerry E. Studds National Marine Sanctuary in Stellwagen Bank, Cape Cod National Seashore (a national park), and Monomoy National Wildlife Refuge and Wilderness Area. Farther offshore, areas of Georges Bank and the Great South Channel are managed for fisheries.

Despite this extensive patchwork of near-shore protection measures, the central area of Nantucket Sound, the area of Nantucket Shoals, large areas of the shelf south of Martha's Vineyard, and Georges Bank are not protected from development. The 1980 nomination of Nantucket Sound as a National Marine Sanctuary by the Massachusetts Office of Coastal Zone Management (CZM) recognized the many values of Nantucket Sound.

Protection or management options can provide various benefits, depending on the option selected. In all cases, protection and management options help to conserve or restore species, habitats, and ecological processes, while providing for appropriate and sustainable economic uses of the resources. The benefits conferred depend on the area's size, location, and permanence, as well as the level and extent of protection provided (Recchia et al., 2001). The degree of limitation on human activities varies greatly, and depends upon the ultimate goals for nominating a protection or management area.

Historically, ocean management areas have included harbors and ports, navigation channels, fisheries closure areas, oil and gas drilling leases, dredged material disposal areas, marine disposal sites, buffer zones around ocean outfalls, munitions testing areas, and sensitive habitats such as coral reefs, seagrass beds, rare species habitat, and others. Typically such ocean management areas are managed for a narrowly defined interest and are generally limited in area.

Designation of marine protected areas in oceanic habitats, as opposed to coastal and onshore habitats, is a more recent phenomenon (Courtney and Wiggin, 2003). Marine protected areas, or MPAs, includes a wide variety of coastal and ocean areas managed according to specific regulations. The term is used in a general sense, although the definition of an MPA used by The World Conservation Union (IUCN) forms the basis for most definitions: "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment." (Courtney and Wiggin, 2003). For comparison, the U.S. Government, in Executive Order 13158, defines an MPA as: "any area of the marine environment that has been reserved by Federal, State, territorial, tribal or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." (Executive Order 13158, 2000).

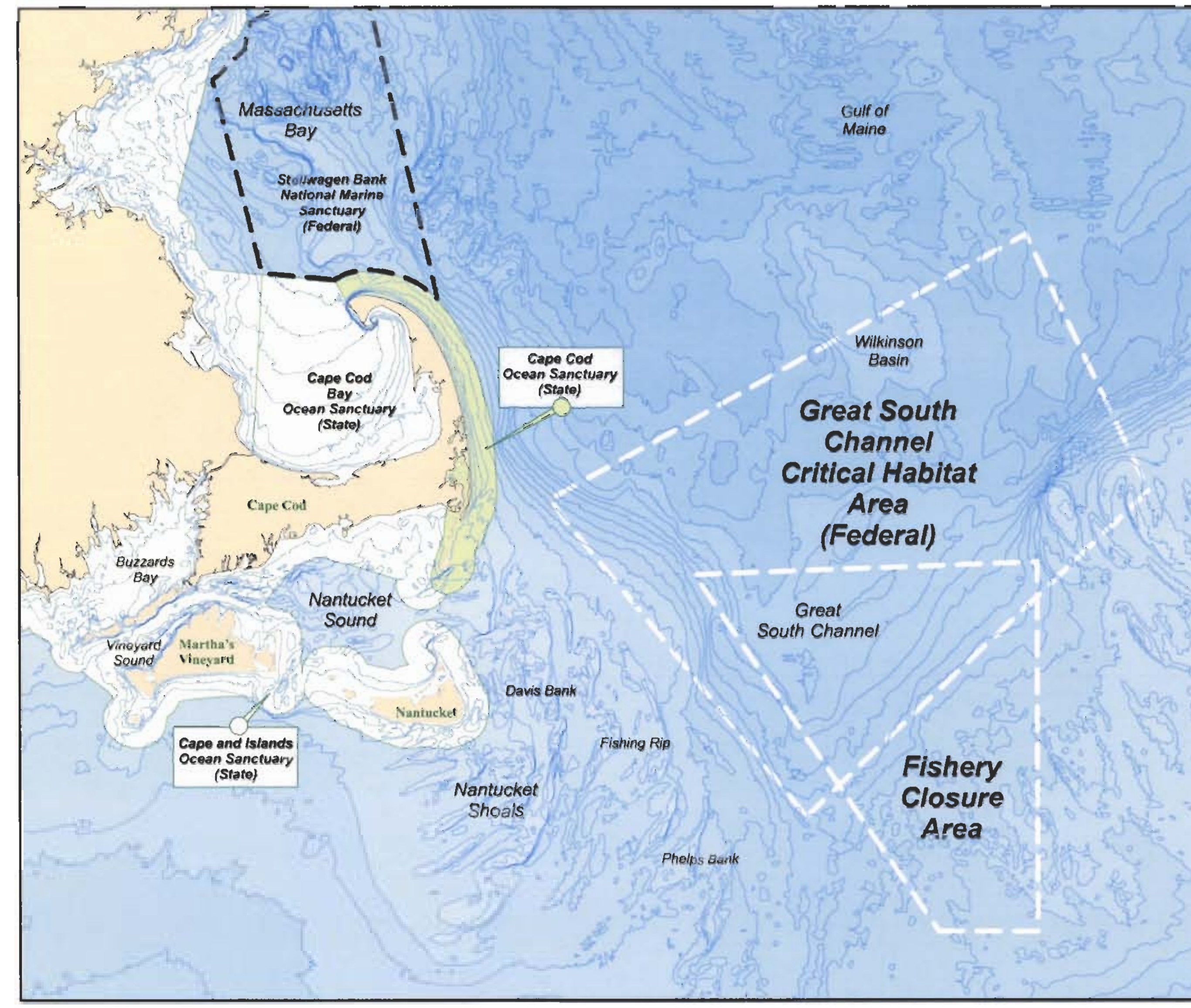


Figure 32. Existing Federal and State Protected Ocean Areas. Data from MassGIS.

Marine protected areas primarily protect and conserve biological diversity, habitat and natural resources, but the range of human uses that may be accommodated, the level of protection, size of area, and type of MPA vary widely. Within an MPA, different areas may be designated for differing uses, depending on the resources present, their value and sensitivity, and human uses. The U.S. Commission on Ocean Policy, in its April 2004 preliminary report, recommended that marine protected areas be used as one management tool to protect and manage important areas of the ocean (U.S. Commission on Ocean Policy, 2004).

The Gulf of Maine provides some examples of local, state and federal approaches to managing coastal and marine areas. The Ocean Conservancy has published a useful and succinct review of "Marine and Coastal Protected Areas in the United States Gulf of Maine Region" (Recchia et al., 2001). Other information on regional values and existing protected coastal and marine areas was obtained from a 2003 white paper by the Provincerown Center for Coastal Studies (Center for Coastal Studies, 2003).

4.1. Federal Ocean Protection

Federal jurisdiction over the nation's ocean and coastal waters extends out to the 200-mile limit, and therefore provides the greatest jurisdiction. At the federal level, there are a number of existing management and/or protection options for coastal and marine areas in the Gulf of Maine and Nantucket Shelf region (Recchia et al., 2001). These are listed below.

- National Marine Sanctuaries
- National Estuary Program
- National Estuarine Research Reserves
- National Wildlife Refuges
- Critical Habitat Areas
- Federal fishery closure areas

The key features of each of these options are briefly described below.

National Marine Sanctuary System (NMS System)

The U.S. National Marine Sanctuaries Act of 1972 allows designation of marine areas to protect critical marine and cultural resources and allow sustainable use. Overall management authority is granted through specific legislation, which may provide coordination and/or supercede other authorities. Canada and Australia have adopted similar legislation to protect marine areas (Canadian Conservation Alreas Act, 2002; Great Barrier Reef Marine Park Act, 1975) (Courtney and Wiggen, 2003).

National Marine Sanctuaries (NMSs) are designated to provide comprehensive protection for their marine resources. NOAA administers the National Marine Sanctuary system. They are established to identify, manage, and conserve marine areas that are nationally significant to "*conservation, recreational, ecological, historical, scientific, educational, cultural, archeological or esthetic qualities*" (Recchia et al., 2001). Generally, National Marine Sanctuary designation prohibits development of non-renewable resources and limits marine discharging, dumping and marine construction. Few NMSs directly regulate fishing or extraction of other living resources.

Stellwagen Bank National Marine Sanctuary is the only NMS in the Gulf of Maine and southeastern Massachusetts. Stellwagen Bank was designated as an Sanctuary in 1992 due to concerns about the potential impacts of proposed and current activities, including oil and gas mining, and because it is prime feeding habitat for many whale species.

National Estuary Program (NEP)

The National Estuary Program (NEP) was established under the federal Clean Water Act to identify, restore, and protect nationally significant estuaries that are threatened by pollution, development or overuse. The NEP focuses on watershed and estuarine protection, particularly water quality protection and related issues. Designation as an NEP does not provide automatic protection nor regulatory protection, but provides a mechanism for various local, state and federal agencies to develop a "Comprehensive Conservation and Management Plan" (CCMP) to protect the site using existing agencies. At each estuary site, a local committee comprising stakeholders, citizens, agencies, scientific and academic institutions, industry, and estuary users develop the CCMP and implement it.

In the Gulf of Maine and southeastern Massachusetts, there are four NEP sites: Massachusetts Bays Program (including Cape Cod and Boston Harbor), the New Hampshire Estuaries Project, the Casco Bay Estuary Project, and the Buzzards Bay Estuary Program (Recchia et al., 2001).

National Estuarine Research Reserves (NERRs)

Under the federal Coastal Zone Management Act, estuarine sites may be designated as a National Estuarine Research Reserve (NERR), forming part of a network of nationwide NERRs. NERRs are chosen to represent habitat types within specific ecoregions and are set up to conduct scientific research over a long term, including long-term monitoring. Other NERR goals are to protect rare species, provide public access, and provide public outreach concerning the marine environment. NERR designation does not automatically confer regulatory protection. Like an NEP site, an NERR is managed locally by local, state and federal agencies using federally-approved management plans that apply state law to coastal and territorial waters. Within an NERR, habitat alteration and coastal development are prohibited, and habitat restoration is frequently a goal. NERRs generally have not restricted fishing or hunting. NERRs are managed by state agencies. NOAA's Estuarine Reserve Division manages the NERR system (Recchia et al., 2001). There is one existing NERR within the Nantucket Shelf region, on Vineyard Sound: this is the Waquoit Bay National Estuarine Research Reserve (WBNERR).

National Wildlife Refuges

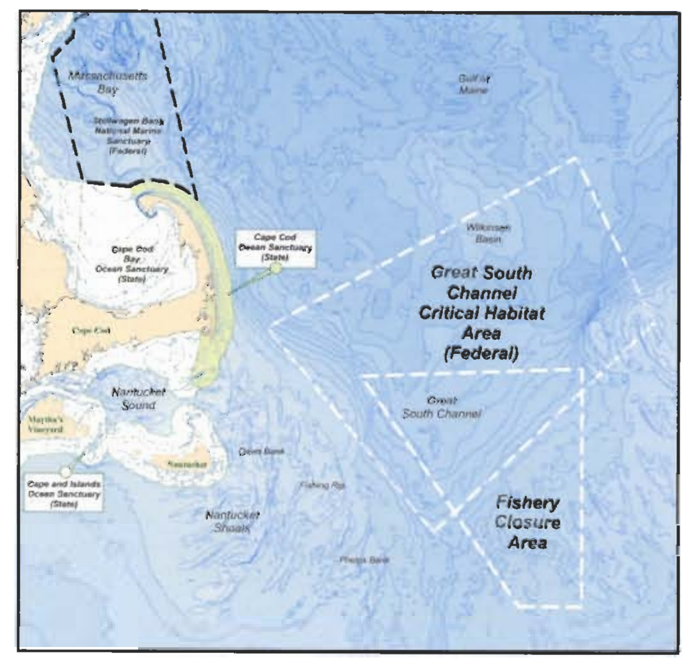
National Wildlife Refuge sites are designated to "*conserve, manage and restore wildlife and their associated habitats for the benefit of present and future generations*." Coastal sites may include islands and nearshore areas to protect migratory birds, seabirds, or anadromous fish (e.g., Atlantic salmon). Terrestrial portions of Refuge sites are owned by the federal government and are protected from development. However, marine resources and habitats are generally not protected. Activities such as cable-laying, marine discharges, dredging, dumping, fishing, hunting, development of non-renewable resources, shoreline alterations, coastal development, and coastal habitat alteration are forbidden. NWRs are managed by the U.S. Fish and Wildlife Service in the Department of the Interior (Recchia et al., 2001).

The Mashpee National Wildlife Refuge and the Monomoy National Wildlife Refuge are the only NWRs in the Nantucket Shelf region. Monomoy National Wildlife Refuge also contains a federally-designated Wilderness Area, which is managed under the 1986 Wilderness Act. In 1970, 94% of the Refuge area was designated as a Wilderness Area, under the 1964 Wilderness Act, which prohibits any development, alteration or disturbance. Monomoy is the only Wilderness Area in southern Massachusetts (http://www.capecodconnection.com/monomoy/monomoy.htm).

Critical Habitat Areas

Under the federal Endangered Species Act, Critical Habitat Areas in specific geographic areas can be designated to conserve, protect and restore threatened or endangered species that may require special protection or management in order to survive. Further development is not necessarily prohibited or restricted. Only activities that are likely to destroy or adversely affect the area or the species or their habitat, or activities that require a federal permit or license or receive federal funding, are affected. Either the U.S. Fish and Wildlife Service or the National Marine Fisheries Service or both may oversee a Critical Habitat Area, depending upon whether the species involved is found on land or in the ocean, respectively.

Two Critical Habitat Areas have been designated in the Gulf of Maine, both to protect the endangered northern Right Whale. Cape Cod Bay and the Great South Channel both are Critical Habitat Areas. Some protection applies year-round, but is strongest when whales are present. Restrictions on fishing apply. Other regulated or limited activities include marine discharging and dumping, non-renewable resource extraction, dredging, and cable-laying (Recchia et al., 2001).



Federal Fishery Closure Areas

Closure of areas to fishing has been shown to be an effective means of restoring depleted fisheries. Fishery closures are areas which are closed to some or all forms of fishing in order to restore depleted species. Typically they are designated to serve a specific fishery objective, such as rebuilding a depleted stock or protecting spawning or nursery areas, rather than conservation. However, other marine species can benefit from fishery closures, depending on the type, duration, and extent of closures. Closures can provide more effective protection to marine ecosystems than more conventional marine protected areas. Fishery closures are designated under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), for "*zones where, and periods when, fishing shall be limited, or shall not be permitted, or shall be permitted only by specific types of fishing vessels or with specified types and quantities of fishing gear*."

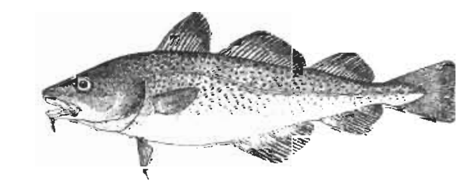
The National Marine Fisheries Services (NMFS) has implemented some fishery closures in the Gulf of Maine, including year-round comprehensive protection for marine species and habitats: the Western Gulf of Maine Closed Area (partly overlaps with Stellwagen Bank National Marine Sanctuary); Closed Area I (partly overlaps Great South Channel Northern Right Whale Critical Habitat Area); and Closed Area II (northeastern Georges Bank). These areas were established to support rebuilding overfished groundfish stocks (cod, haddock, flounder) and are closed year-round to many types of fishing, including bottom trawling. Additional areas are closed seasonally or to some types of fishing activities (Recchia et al., 2001).

Of the several federal options described above, only National Marine Sanctuaries, Federal Fishery Closure Areas, and Critical Habitat Areas can be applied to open ocean areas. NEPs and NERRs are restricted to nearshore estuaries, although Nantucket and Vineyard Sounds can be considered estuaries. Federal Wilderness Areas and National Parks have not been applied to open ocean areas, although the recently-designated Boston Harbor Islands National Park incorporates coastal waters.

4.2. State Ocean Protection

State protection of coastal waters is limited to state waters, which extend only out to the 3 mile-limit from Mean High Water. Existing state managed/protected areas in the Gulf of Maine (Figure 32, Recchia et al., 2001).

- Massachusetts Ocean Sanctuaries
- State fishery closure areas
- State Essential Habitat for Endangered Species



The key features of these state marine protection areas are described below.

Massachusetts Ocean Sanctuaries

State ocean sanctuaries in Massachusetts protect the ecology and the appearance of the ocean and the seabed from exploitation, development, or other activity that would alter or endanger these resources. State ocean sanctuaries extend from Mean Low Water to the 3-mile state limit. Designation does not regulate fisheries or extraction of other living marine resources, but does limit discharges, dumping, extraction of non-renewable resources, marine construction, and shoreline alteration. The program is administered by the Massachusetts Coastal Zone Management Office and Department of Environmental Management (Recchia et al., 2001).

There are three existing Ocean Sanctuaries in southern Massachusetts: Cape Cod Bay Ocean Sanctuary, Cape Cod Ocean Sanctuary (along the Outer Cape), and the Cape and Islands Ocean Sanctuary. There are two additional Ocean Sanctuaries in northern Massachusetts (South Essex Ocean Sanctuary and North Shore Ocean Sanctuary) (Figure 32, from MassGIS data). The three Ocean Sanctuaries in southern Massachusetts exclude significant areas of Nantucket Sound, Nantucket Shoals, and nearby ecologically similar areas.

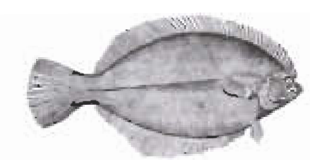
Massachusetts State Fishery Closure Areas

Like the fisheries closures implemented under the federal Magnuson-Stevens Act in federal waters, the Massachusetts Division of Marine Fisheries implements fishery closures in Massachusetts state waters. Similar to the federal closures, most closures are seasonal. There are no areas closed to all fishing. State estuaries and harbors are designated as Inshore Net Areas, within which fishing nets and mobile gear (i.e., bottom trawls and scallop dredges) are generally prohibited year-round, but scallop dredges are allowed pursuant to town regulations. (Recchia et al., 2001)

State Habitat for Rare Species

The Massachusetts Division of Fisheries and Wildlife oversees protection of rare and endangered species, vernal pools, and critical or endangered habitats, through its Natural Heritage and Endangered Species Program (NHESP). Critical habitat for rare species is identified and mapped, and provides the basis for reviewing and commenting upon proposed projects in or near rare species habitat. The Massachusetts Endangered Species Act (MESA) and portions of other resource regulations (e.g., state Wetlands Protection Act regulations, etc.) protect rare species and prohibit or limit disturbance or development of habitat which has been documented to contain state-listed species. All federally listed species occurring in Massachusetts are also state-listed to avoid discrepancies. State habitat for rare species is generally very limited in area and is delineated based on documented observations of state-listed species and information on their habitat needs.

4.3. Other Approaches - Marine Protected Areas and Ocean Zoning



Marine protected areas for ocean protection provide one approach for comprehensive ocean management and protection. This is a tool that has become available in the last several years since a Presidential Executive Order was issued in 2000 calling for increased designation of Marine Protected Areas (MPAs) to protect ocean resources (Executive Order 13158, 2000). The U.S. Commission on Ocean Policy, in its 2004 report, recommended that marine protected areas be used as one management tool to protect and manage important areas of the ocean (U.S. Commission on Ocean Policy, 2004).

Executive Order 13158 on Marine Protected Areas defines a Marine Protected Area (MPA) as: "any area of the marine environment that has been reserved by Federal, State, territorial, tribal or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." (Executive Order 13158, 2000). For comparison, the World Conservation Union (IUCN) defines a Marine Protected Area as: "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment." (Courtney and Wiggin, 2003).

Marine protected areas include a wide variety of coastal and ocean areas managed according to specific regulations. Marine protected areas are intended to protect and conserve biological diversity, habitat, natural resources, sustainable uses, and cultural heritage for future generations. The range of human uses that may be accommodated, the level of protection, size of area, and type of MPA vary widely. Within an MPA, different areas may be zoned for differing uses and degrees of activity, depending on the resources present, their value and sensitivity, and sustainable human uses (see NOAA and Department of the Interior website on Marine Protected Areas at http://www.map.gov/what_is_an_mpa/sup_terminology.html).

Designation, establishment or recommendation of a Marine Protection Area, based on Executive Order 13158, is undertaken by the Department of Commerce (NOAA) and the Department of the Interior, with input from other Federal agencies (e.g., Department of the Interior, Environmental Protection Agency, USAID, Department of State, Department of Transportation, the National Science Foundation, Department of Defense, and others). Recommendation and establishment of an MPA requires science-based identification and prioritization of natural and cultural resources for protection, assessment of ecological linkages, assessment of areas needing special protection of natural and cultural resources, identification of threats and gaps in protection, identification of emerging threats and user conflicts, identification of equitable management solutions to reduce threats and conflicts, assessment of the economic effects of such management, and identification of linkages with international marine protected area programs ((Executive Order 13158, 2000).

Ocean zoning is a regulatory plan to implement planning and protection. Ocean zoning consists of the division of a marine area into districts and within these districts regulating uses to achieve specific goals. The uses may differ between districts, depending on the goals of each district. Certain uses may be prohibited in some zones, due to the sensitive nature of the zone, but may be allowed in other zones where sensitivity is less or non-existent. Ocean zoning requires development of a map that outlines the boundaries of the districts, followed by development and implementation of a set of regulations for each district or zone created.

The advantages of ocean zoning include:

- Reduction of user conflicts by separating incompatible uses;
- Distributing uses according to an area's suitability for that use;
- Providing a flexible approach to management and protection on a site-specific basis;
- Adding predictability to the management and regulatory system; and
- Providing a way to coordinate management of a region (Courtney and Wiggin, 2003).

Ocean zoning faces some challenges. These are:

- Multi-dimensional nature of the ocean (physically and legally);
- Lack of consistent spatial data;
- Lack of accurate, up-to-date information on the resources;
- Importance of a scientific objective in setting up boundaries;
- Accessibility to agencies, users and stakeholders; and
- Movement of living and non-living resources across zoning boundaries.

Some examples of marine zoning already exist. These include the Town of Edgartown Surface Water District on Martha's Vineyard, including all waters seaward of Mean High Water (MHW) in the town's harbors and coves; Town of Orleans Watershed Zoning for Pleasant Bay ACEC; New Jersey Marine Conservation Zoning to protect critical coastal habitat from Mean High Water out to 300 feet in the area of the Sedge Islands; National Marine Sanctuaries; and Marine Parks.

Courtney and Wiggen (2003) proposed ocean zoning for the Gulf of Maine, following an Ocean Zoning Forum held in 2002 by the Gulf of Maine Council on the Marine Environment. The goal of the Council was to promote marine sustainability in the Gulf of Maine; that is, manage uses, protect habitat and conserve biodiversity in the marine environment.

photo: NOAA photo library


The Buzzards Bay oil spill. photo: The Coalition for Buzzards Bay


WHOI scientist investigating an oil spill. photo: WHOI


Coastal storm. photo: WHOI Sea Grant

5. KEY PRINCIPLES OF OCEAN MANAGEMENT

Given the ecological and human values of the Nantucket Shelf region, existing and potential management issues, increasing population pressures, and the Ocean Commission's recommendations regarding the need for ocean protection, it is time to consider nominating the Nantucket Shelf region for marine protection. What are the key principles of sound ocean management?

5.1. Ecosystem-Based Management

Ecosystem-based management and protection of resources should be one of the most important goals of marine protection (U.S. Ocean Commission on Ocean Policy, 2004). Ecosystem-based management is based on the principle that the best resource management and protection is firmly grounded in a sound understanding of the ecosystems being managed. Ecosystem-based resource management takes account of the complex relationships between all living organisms, including humans, and the environment in which they live. Complex issues that cross traditional jurisdictional boundaries and disciplines can be addressed (U.S. Commission on Ocean Policy, 2004).

Ecosystem-based management also incorporates change. Ecosystem-based decisions acknowledge that the environment can change, even in the absence of anthropogenic influences. Adaptive management also allows for new and improved scientific information and management tools to be used as they become available (Busch et al., 2003).

Ecosystem-based management is an alternative to traditional management of marine resources (e.g., single-species or single-resource management) because it is multidisciplinary and interdisciplinary. The U.S. Commission on Ocean Policy has recommended that ecosystem-based management approaches be used for protection and management of marine resources because of the complexity of marine ecosystems (U.S. Commission on Ocean Policy, 2004).

Ecosystem-based decisionmaking includes addressing the following:

1) Consideration of the health and vitality of ecosystems into the indefinite future;
2) The larger landscape and connections among other landscapes, and
3) Stakeholders' perspectives and human goals.

Ecosystem-based management requires attention to ecosystem integrity, interagency cooperation, specific management measures for specific areas, and time-series data for multiple species and habitats.

The benefits of utilizing ecosystem-based management include the following:

- Avoiding costly mistakes. Ecologically-based decisionmaking ensures that costly ecological mistakes in resource management are avoided;
- Well-coordinated, comprehensive management that takes account of natural processes. Entire ecological processes (feeding relationships, nutrient cycling, production, etc.) and ecological units (e.g., colonies, species, breeding populations, age-classes, etc.) are protected and managed in a comprehensive manner rather than managing for one or two species or a single process. This helps to avoid a piecemeal, uncoordinated approach to resource management.
- Boundaries are based on natural features. Resource areas are delineated along natural ecological boundaries rather than artificial political boundaries, allowing for efficient management of an ecological resource or function;
- Stakeholder issues are taken into account. Stakeholder concerns and human issues are considered;
- Adaptive management allows for improvements and change as information and knowledge improve. Resource management takes account of change in the environment and changes and improvements in knowledge and management tools. Adaptive management is described in more detail below.

Recently, ecosystem-based resource management in the marine realm has been proposed by several organizations. The U.S. Commission on Ocean Policy recommended that ocean and coastal managers use ecosystem-based management.

5.2. Integrated Coastal and Ocean Management

Integrated coastal and ocean management is a resource management principle that is applicable to managing and protecting a large and diverse region such as the Nantucket Shelf. Integrated coastal and ocean management can be defined as "*a continuous and dynamic process by which decisions are made for the sustainable use, development, and protection of coastal and marine areas and resources. First and foremost, the process is designed to overcome the fragmentation inherent in both the sectoral management approach and the splits in jurisdiction among levels of government at the land-water interface. This is done by ensuring that the decisions of all sectors (e.g., fisheries, oil and gas production, water quality) and all levels of government are harmonized and consistent with the coastal policies of the nation in question. A key part of ICM is the design of institutional processes to accomplish this harmonization in a politically acceptable manner.*" (Cicin-Sain and Knecht, 1998). The goals of integrated coastal and ocean management are:

- To achieve sustainable development of coastal and marine areas;
- To reduce vulnerability of coastal areas and their inhabitants to natural hazards;
- To maintain essential ecological processes, life support systems, and biological diversity in coastal and marine areas;

In addition, the processes involved in integrated coastal and ocean management are characterized by the following:

- Multi-purpose goals, planning and activities
- Analyzes implications of development, conflicting uses and interrelationships among physical processes and human activities, and
- Promotes linkages and harmonization between sectored coastal and ocean activities.

Integrated coastal and ocean management provides a flexible, protective, science-based approach that incorporates stakeholder and public interests, in a manner that is consistent with adaptive management principles (Cicin-Sain and Knecht, 1998).

5.3. Adaptive Management

Adaptive management is a third goal of resource protection and management. Adaptive management involves developing resource management plans and policy based on up-to-date scientific information concerning resources, monitoring the effects of these plans and policies on resources, modifying plans and policies as needed to achieve overall resource goals, and using science and policy to formulate and modify plans and policies. Future planning is done in a flexible manner to accommodate unforeseen events (Walter et al., 2000; Allison et al., 2003; Walters, 1997).

Although large areas of the Nantucket Shelf Region remain largely unexplored, there is sufficient information to indicate that the entire Nantucket Shelf Region provides significant ecological and recreational values. The U.S. Commission on Ocean Policy (2004) recommends that marine protection and management be based on sound science, but where such science is incomplete, protection and management actions should nevertheless proceed and build the capacity for collecting relevant scientific information. An adaptive management approach is recommended for the Nantucket Shelf Region, in addition to ecosystem-based management and integrated management.

6. CRITERIA FOR DESIGNATING MARINE PROTECTED AREAS

Criteria are measures of value, and the designation of marine protected areas begins with identifying criteria for judging the need for and type of protection and management. The identification of suitable criteria for designating protection is a necessary step in identifying an area to be protected, whether it is on land or in the ocean.

Possible criteria for designating a marine protected area fall into two categories: ecological criteria and socioeconomic criteria. The science and social science of resource protection in the U.S. has matured in the last century and a half since the first national parks were designated in the late 1800's. Resource managers today are keenly aware of the need to take account of socioeconomic factors as well as ecological factors in designing, managing and protecting natural resources. This is especially true for marine resources, which span a wide geographic area.

Examples of possible ecological and socioeconomic criteria for designation of a marine protected area are described below.

6.1. Ecological Criteria for Marine Reserve Design

A good example of ecological criteria for a marine reserve is provided by a study of the design of a network of marine reserves for conservation and fisheries management in the Channel Islands off the California coast (Airame et al., 2003). The Channel Islands are managed under a variety of state and federal jurisdictions, including the Channel islands National Park, Area of Special Biological Significance, Channel Islands Biosphere Reserve, Channel Islands National Marine Sanctuary, and Santa Barbara Channel Ecological Preserve. The need to evaluate and improve resource management was driven by a steady deterioration of marine resources despite the state and federal management overlays.

Agencies, organizations, fishermen, environmentalists, and others first developed a set of goals. These goals are listed below (from Airame et al., 2003):

Table 8. Goals for Siting of a Marine Reserve Network in the Channel Islands, California. (Airame et al., 2003).

Goal Categories	Goals for Marine Reserves
Ecosystem biodiversity	To protect representative and unique marine habitats, ecological processes, and populations of interest in the Channel Islands National Marine Sanctuary
Sustainable fisheries	To achieve sustainable fisheries by integrating marine reserves into fisheries management
Economic variability	To maintain long-term socioeconomic viability while minimizing short-term socioeconomic losses to all users and dependent parties
Natural and cultural heritage	To maintain areas of visitor, spiritual, and recreational opportunities which include cultural and ecological features and their associated values
Education	To foster stewardship of the marine environment by providing educational opportunities to increase awareness and encourage responsible use of reserves

Table 8 provides a succinct yet comprehensive set of goals for a marine protection area. Based on these goals, the stakeholders then developed a set of regional ecological criteria, or set of ecological values, to help identify areas and suites of potential reserves. The concept of suites of reserves includes networks of reserves that provide organized management of ecological features throughout several areas or overlapping jurisdictions in order to achieve goals. Thus the ecological criteria are intended to overcome several criticisms of conventional resource protection: 1) Protection of a single resource without consideration of other resources can cause overall ecosystem damage; 2) A single resource that is distributed throughout several jurisdictions may not be managed adequately throughout all of the jurisdictions because of inconsistent goals; and 3) Existing types of individual reserves may not be adequate to manage an entire ecosystem.

The regional ecological criteria developed by the Channel Islands stakeholders are given in Table 9.

Table 9. Application of ecological criteria for marine reserve design in the Channel Islands, Southern California. (Airame et al., 2003).

Ecological Criteria	Application to the Channel Islands	Limitations
Biogeographical representation	Three major biogeographical regions were identified using data on biota and substrate type.	Boundaries of biogeographical regions are not fixed.
Habitat representation	Representative and unique marine habitats in each biogeographical region were classified using depth, exposure, substrate type, dominant plant assemblages, and a variety of additional features.	Data on the distributions of habitat types may be limited.
Habitat heterogeneity	This was not incorporated as a specific criterion, but the analysis required representation of 30-50% of all habitats within the smallest area possible, this selecting areas of high habitat heterogeneity.	Data on the distributions of habitat types may be limited.
Vulnerable habitats	To ensure adequate representation, vulnerable habitats were considered as unique habitat types.	Data on the distributions of vulnerable habitats may be limited.
Species of special concern and critical life history stages	Island coastlines and emergent rocks were weighted according to the distributions of sea haul-outs and seabird colonies. The algorithm selected areas of high sea and bird diversity. Other species were not weighted due to insufficient data on their distributions.	Data on distributions and life-history characteristics of species of special concern may be limited.
Exploitable species	Habitats likely to support exploitable species, especially rockfishes (e.g., emergent rocks and submerged rocky features) were included for specific representation.	Data on distributions and life-history characteristics of exploitable species may be limited.

(Table 9. continued)

Ecosystem functioning and linkages	Not used.	Determining the extent to which ecosystem linkages constrains reserve design may be difficult.
Ecosystem services	Locations of Channel Islands National Park kelp forest monitoring sites were not included as a formal criterion, but borders of potential reserves will be adjusted, if needed, to include some of those sites.	Sufficient information on ecosystem services may not be available.
Human threats and natural catastrophes	The reserve size needed to meet reserve goals in a stable environment was multiplied by a factor that accounts for the frequency of severe disturbances.	Data on the frequency of severe disturbances may be limited.
Size and connectivity	At least one, and no more than four, reserves should be placed in each of the three biogeographical regions. For one region (650 square nautical miles), two to three reserves was recommended.	Optimal number of reserves will generally depend on the size of each biogeographical region. Reserve placement will depend on plant and animal dispersal among sites.

Channel Islands National Marine Sanctuary
Marine Mammal Sightings Database
checklist available on the Internet

These ecological criteria provide a good example of the way in which ecological factors are incorporated into resource management and protection, resulting in ecosystem-based management. Although the criteria were developed for the Channel Islands, they are applicable in their general sense to the Nantucket Shelf region as well. Specific details of each ecological criterion would have to be developed for the Nantucket Shelf Region.

6.2. Combined Socioeconomic and Ecological Criteria for Siting of a Marine Protection Area

In addition to ecological criteria, socioeconomic criteria are important in designing and siting a marine protection area. An example of socioeconomic criteria for selecting marine protection areas was summarized by Roberts et al. (2003), based on information from the Swedish Environmental Protection Agency and others. This example is reproduced in Table 10.

Table 10. Social and economic criteria used to select the locations of marine protected areas. (Roberts et al., 2003).

Value	Criteria
Economic	Number of fishermen dependent on the area. Value for tourism. Potential contribution of protection to enhancing or maintaining economic value.
Social	Ease of access. Maintenance of traditional fishing methods. Presence of cultural artifacts/wrecks. Heritage value. Recreational value. Educational value. Aesthetic appeal.
Scientific	Amount of previous scientific work undertaken. Regularity of survey or monitoring work done. Presence of current research projects. Educational value.
Feasibility / practicality	Social/political acceptability. Accessibility for education/tourism. Compatibility with existing uses. Ease of management. Enforceability.

(Information for Table 10 was summarized by Roberts et al. (2003) from the Swedish Environmental Protection Agency (Naturvårdsverket, 1995; Kelleher and Kenchington, 1992; Nordic Council of Ministers (Nordiska Ministerrådet 1995); Salm and Price, 1995; Hockey and Branch, 1997; Agardy, 1997; and Nilsson, 1998).

http://www.internat.naturvardsverket.se/index.html

photo: Claes Grundsten/Bildhuset

The relative importance of socioeconomic vs. ecological criteria, however, can differ, depending on the area, or depending on timing. For example, in the early stages of considering marine protection for an area, information on ecological and/or socioeconomic resources may not be complete. Typically, a marine protected area such as an estuarine research reserve might first be identified by its ecological values, followed by a growing appreciation of its socioeconomic values. Given that the appreciation of socioeconomic vs. ecological values may differ in time and according to the particular area, how can socioeconomic and ecological criteria be incorporated into a single system of criteria?

The answer lies in developing marine reserve networks that can maintain ecological values, such as biodiversity and ecosystem functioning at large scales, and where the values of ecosystem goods and services for people depend upon meeting the ecological goals, as described in Roberts et al. (2003).

This approach is applicable to the Nantucket Shelf Region, where socioeconomic values (appreciation of natural beauty, tourism, recreation, marine education) revolve about the ecological and natural values of the region. The Nantucket Shelf Region may be an example of an area where the socioeconomic values are important and well-defined in the public's mind, while appreciation of ecological values may be lagging due to gaps in scientific understanding.


photo: NOAA photo library

7. EVALUATION OF POSSIBLE MARINE PROTECTION AND MANAGEMENT APPROACHES FOR THE NANTUCKET SHELF REGION

In this section, possible management and protection models are evaluated in terms of their potential usefulness for protecting and managing the values of the Nantucket Shelf Region. Different types of marine protected areas afford differing degrees of protection.

Of the many kinds of MPAs considered, most are suitable for managing or protecting watershed or coastal areas, and their marine jurisdiction ends at either a nearshore boundary (e.g., Mean High Water), a specified coastal boundary or at most to the limit of jurisdiction of the agency that oversees their management.

Currently, seven types of MPAs address or could address strictly marine or marine estuarine areas:

- National Estuary Program sites;
- National Estuarine Research Reserves;
- National Marine Sanctuaries;
- Critical Habitat Areas for marine organisms;
- Fishery Closed Areas or other federally-managed fisheries areas;
- Massachusetts Ocean Sanctuaries; and
- Ocean zoning.

Of these strictly marine or estuarine MPAs, only Fishery Closed Areas and Critical Habitat Areas strictly limit or temporarily prohibit fishing activities. Most of these allow or limit other activities, while National Marine Sanctuaries and the Cape Cod National Seashore prohibit development of nonrenewable resources.

Of these MPAs, federal jurisdiction is the greatest, up to 200 miles from shore. Thus National Marine Sanctuaries, federal Critical Habitat Areas, and federal Fishery Closure Areas provide the most jurisdiction. Extensive jurisdiction is important for an area so large as the Nantucket Shelf, portions of which lie outside of the 3-mile state jurisdictional limit.

The degree of protection afforded by MPAs also differs greatly. Most MPAs allow a variety of activities. Some limit or restrict activities. Only National Marine Sanctuaries prohibit specific activities (development of non-renewable resources).

National Marine Protected Area

State jurisdiction is generally limited to the 3-mile limit, and could not be used to protect the resources of the outer Nantucket Shoals, or the central portion of Nantucket Sound, or the shelf south of Martha's Vineyard, much less the Great South Channel. The most extensive jurisdiction is federal. For an area as large as the Nantucket Shelf region and its ecosystems, federal jurisdiction would provide the best coverage. This narrows the options to National Marine Sanctuary, Federal Fishery Closure Areas, Critical Habitat Area, or other Federal option.

While fisheries management within the area of Nantucket Shelf is highly desirable, the prohibition of fishing is not. Human uses of the area include recreational fishing and shellfishing, and these are important to the local economy. Too, the important functions of the Shelf region are nursery habitat and migration habitat. These functions can be protected through careful management for sustainable fisheries rather than prohibition of fishing. Protection of the area solely for fisheries also would overlook many of the other important natural and human values of the Nantucket Shelf.

The areas used by endangered species for breeding and nesting should be protected as Critical Habitat Areas. In particular, nearly the entire North American population of Roseate terns passes through the Cape and Islands region and stops in Monomoy to nest and feed. Terns also fly to Buzzards Bay, which is a National Estuary. Existing Critical Habitat Areas, such as the Great South Channel, which may be ecologically linked, should be incorporated as well. But designation of the entire Nantucket Shelf as a Critical Habitat Area is probably not warranted.

Outreach and scientific research are important activities that should be provided. Scientific research in particular needs to be ramped up in order to understand a coastal area that is just at our doorstep, so to speak. Designation as a National Estuary or National Estuarine Research Reserve (NERR) would provide these important activities of outreach and research but would not provide much regulatory protection. NEPs or NERRs can be overlaid on another type of MPA in order to provide protection, outreach and research.

A National Marine Protected Area (MPA), managed by NOAA, would provide the most comprehensive, flexible, and yet protective form of protection and management, particularly if it incorporates ocean zoning. Ocean zoning can be done within the context of one or more of these MPAs, and provides a flexible tool for managing large areas, subject to the shortcomings described above. For example, a Marine Protected Area may be divided into management and use zones depending on the need to protect sensitive resources, uses, and appropriate ecosystem-based management tools. Ocean zoning provides a highly flexible and effective tool. Ocean zoning areas would need to be designated, but could be developed around the major ecoregions and values already identified.

The Nantucket Shelf Region could be designated as a new federal Marine Protected Area, zoned into different ocean zones according to the relative importance of ecological and socioeconomic factors within each of the zones.

Example of Possible Ocean Zones Within the Nantucket Shelf Region: (see Figure 33)

Ocean Zone 1: National Marine Sanctuary designation for Nantucket Sound, Vineyard Sound, and Buzzards Bay. The designation would provide the highest degree of protection for both ecological and socioeconomic values, and would acknowledge the high degree of socioeconomic value placed upon the open ocean. This area is characterized by aesthetic and cultural values, active recreational boating and fishing, marine science and education, increasing coastal development, a coastal economy that is heavily dependent on the natural scenery, many management issues, and a network of several existing coastal protected or managed areas (Cape Cod National Seashore, Monomoy National Wildlife Refuge and Wilderness Area, Waquoit Bay NERR, Buzzards Bay National Estuary Program, Mashpee National Wildlife Refuge, and Massachusetts Ocean Sanctuaries). Other features in common include their marine estuarine nature; highly dynamic sediment and water processes; important fisheries and nursery functions; important avian habitat including nesting, breeding and airspace habitat. This zone is characterized by well-defined socioeconomic values that revolve about the undeveloped ocean, and less well-defined ecological values, particularly marine ecological values, that should be the subject of further study. Hazards include rising sea level and moderate to high coastal erosion, resulting in high coastal vulnerability. The area represents a moderate to high risk for shipping due to its shallow depth, variable shoals, and rapid currents.

Ocean Zone 2: Nantucket Shoals and Georges Bank. These two areas share many ecological and socioeconomic features: shallow sandy benthic habitat; high-energy environment (wind, waves and currents); important fisheries habitat; distance from land; ecological transition area between Great South Channel and the two Sounds; moderate recreational use; high cultural value; and a hazard to shipping. Georges Bank is actively managed for fisheries and fishery closures are in effect in some areas.

Ocean Zone 3: Great South Channel. This area is important for both ecological reasons (feeding grounds for endangered Right whales, fish and other marine animals, high productivity) and socioeconomic reasons (commercial shipping). The area contains a federal Critical Habitat for the Right whale and the fishery is seasonally closed.

Ocean Zone 4: Outer Continental Shelf. This area includes the large area of continental shelf south of Martha's Vineyard, Nantucket Shoals, and the Great South Channel, out to the edge of the continental shelf. The area is characterized by its open ocean character highly dynamic water processes, high rate of coastal erosion, moderate recreational value, fisheries habitat, high aesthetic value, and low to moderate risk for shipping. Relatively little is known about the ecological values of this area.

Figure 33. Ocean Zones Within a Nantucket Shelf Marine Protected Area:

1 **Ocean Zone 1:** National Marine Sanctuary designation for Nantucket Sound, Vineyard Sound, and Buzzards Bay.

2 **Ocean Zone 2:** Nantucket Shoals and Georges Bank.

3 **Ocean Zone 3:** Great South Channel.

4 **Ocean Zone 4:** Outer Continental Shelf.

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